A MANUAL OF Experiments and Projects in PHYSICS

H. CLYDE KRENERICK
NORTH DIVISION HIGH SCHOOL
MILWAUKEE, WISCONSIN

D. C. HEATH AND COMPANY
BOSTON NEW YORK CHICAGO
ATLANTA SAN FRANCISCO DALLAS
LONDON

A MANUAL OF Experiments and Projects in PHYSICS

H. CLYDE KRENERICK
NORTH DIVISION HIGH SCHOOL
MILWAUKEE, WISCONSIN

D. C. HEATH AND COMPANY
BOSTON NEW YORK CHICAGO
ATLANTA SAN FRANCISCO DALLAS
LONDON

3 G 1

PRINTED IN THE UNITED STATES OF AMERICA

PREFACE

The distinction between this manual and the large number of manuals already published is that it is written to be used when there is perfect correlation between laboratory work and classroom discussion; when, if desired, the laboratory work precedes the lecture-room presentation. It is written not as a laboratory text, but to accompany a text and each experiment presupposes that the student is familiar with the content of some definite assignment.

The author has for many years assigned the topic and the next day sent the student to the laboratory to test for himself the subject of his lesson before his interest and enthusiasm was cooled by classroom demonstration and discussion.

The nature of the experiment and the apparatus has been modified so that the great majority of students are able to complete the experiment and have their work accepted in one period of fifty minutes.

For the exceptional student who finishes his experiment early in the period, there is an optional part, which is a continuation of some phase of the experiment or a problem applying the principle involved.

When the laboratory work is to correlate perfectly with the classroom discussion and become an integral part of the teaching method, it is necessary that all students work on the same experiment. For best results it is desirable that they work individually on the large majority of experiments. The apparatus required for the experiments in Part I is comparatively inexpensive, and the consequent cost for sets of twenty-four in nearly all experiments is not prohibitive in the average school. A complete list of the apparatus needed for each experiment is given at the back of the manual.

Mechanics, Sound, and Light are arranged for the first semester and Heat and Electricity for the second semester. This sequence of subjects is best if the projects in Part II are to be considered in a group. However no experiment or group of experiments is based on knowledge obtained in some previous experiment, consequently they may be performed in any desired order.

There are many desirable experiments or tests where the apparatus is of such a nature and cost that sets are impossible. Twenty-one such experiments or projects are given in Part II. These projects

are of a practical nature, the principles of physics applied to practical problems.

The author's method has been to set up the apparatus for the projects in Part II some five or six weeks before the close of the semester. They serve as a laboratory review of the semester's work. Here the students work in groups of two, or individually if they wish, and perform as many as possible, making their own selections.

TABLE OF CONTENTS

PART I. EXPERIMENTS

PART II. PROJECTS

EXPERIMENTS

PHYSICS MANUAL

Experiment 1 — ENGLISH AND METRIC UNITS

(*a*) Linear Measurements

Measure the length of a rectangular block in both inches and centimeters and record in tabular form as indicated below. To use the meter stick properly, place the edge against the surface to be measured so that the eye is in line with the graduations. When measuring in the English units estimate to the thirty-second of an inch and record in decimal form expressed to the second place.

From the results obtained, compute the number of centimeters in one inch. Express to the second decimal place. Consult your text or manual and record the correct values.

(*b*) Surface Measurements

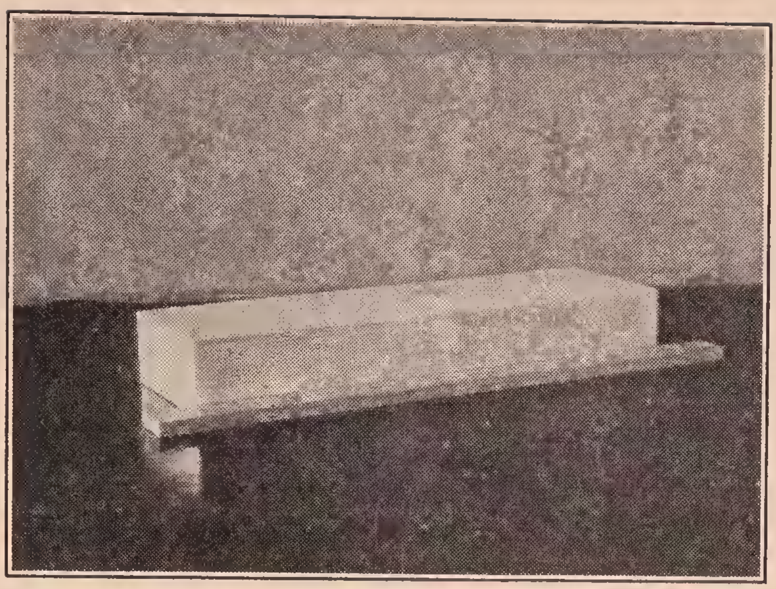
Measure the width of the block in both inches and centimeters and compute the area of the top of the block in square inches and in square centimeters.

From the results obtained, compute the number of square centimeters in one square inch.

(*c*) Volume Measurements

Measure the thickness of the block and determine its volume in cubic inches and in cubic centimeters.

Compute the number of cubic centimeters in one cubic inch.



Tabulation

System of Units	English	Metric
Length of block	.... in.	.... cm.
No. of cm. in one inch		.... cm.
Correct equivalent		.... cm.
Width of block	.... in.	.... cm.
Surface of top of block	.... sq. in.	.... sq. cm.
No. of sq. cm. in a sq. in.		.... sq. cm.
Correct equivalent		.... sq. cm.
Thickness of block	.... in.	.... cm.
Volume of block	.... cu. in.	.... cu. cm.
No. of cu. cm. in a cu. in.		.... cu. cm.
Correct equivalent		.... cu. cm.

Optional

Compute the number of kilometers in a mile. The square decameter is called an are and the square hectometer is called a hectare. They are used in measuring land. Determine the number of ares in an acre. Use the correct equivalents. One acre contains 160 square rods.

Experiment 2 — VOLUME OF CYLINDER — VERNIER CALIPER

The vernier caliper consists essentially of two scales, one of which slides along the other. The shorter or sliding scale is called the vernier; the longer the fixed scale. The object to be measured is placed between the jaws which are so made that, when they are in contact, the zero of the vernier is opposite the zero of the fixed scale. Hence measuring with the caliper is in reality finding the distance between the two zero lines.

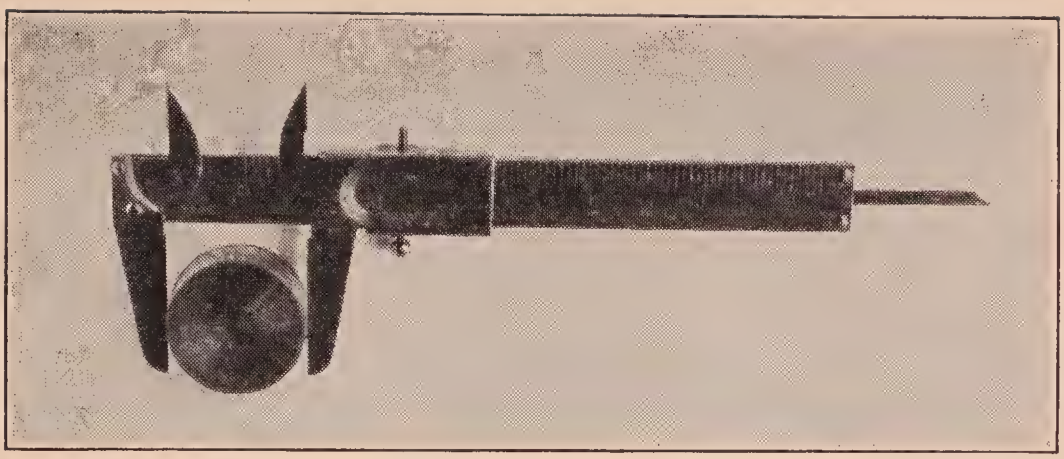
Determine the magnitude of the smallest division of the fixed scale. Compare the sliding scale with the fixed scale and determine the length of the vernier. Compute the magnitude of each division of the vernier.

The difference in length between one division of the fixed scale and one of the vernier is called the "least count." It determines to what part or fraction of the fixed scale division the measurement can be taken.

Set the caliper so that the reading or distance between the jaws is exactly 2 cm.; 2.3 cm.; 2.37 cm. When set for the last reading, take the caliper to your instructor for verification.

Measure accurately the diameter, circumference, and length of a brass cylinder. To measure the circumference wrap a piece of writing paper closely around the cylinder and make a pinhole through the overlapping edges. Remove the paper and measure the circumference by placing the sharp-pointed jaws in the two pinholes.

Compute the ratio of the circumference to the diameter, the area of the end of the cylinder, and the volume of the cylinder.



Tabulation

Smallest division of fixed scale	....
Length of the vernier	....
Smallest division of vernier	....
Least count of caliper	....
Diameter of cylinder	....
Length of cylinder	....
Circumference of cylinder	....
Circumference ÷ diameter	....
Area of end of cylinder	....
Volume of cylinder	....

Optional

In a like manner determine the first six records in the tabulation using the English scale on the caliper. Have your reading for the length of the cylinder verified by taking your caliper to the instructor.

Experiment 3 — VOLUME OF SPHERE — MICROMETER SCREW

The micrometer screw is an instrument for measuring small dimensions with great accuracy. The graduation on the outer cap is called the circular scale; that on the hub, the linear scale. The instrument should be held in the left hand and the screw adjusted by placing the thumb and finger of the right hand on the ratchet head, which is the outer and smaller milled head.

When closing the jaws or when placing objects between the jaws, always move the screw by turning the ratchet head, and continue to turn it until two clicks are heard. In this way the pressure will be always the same.

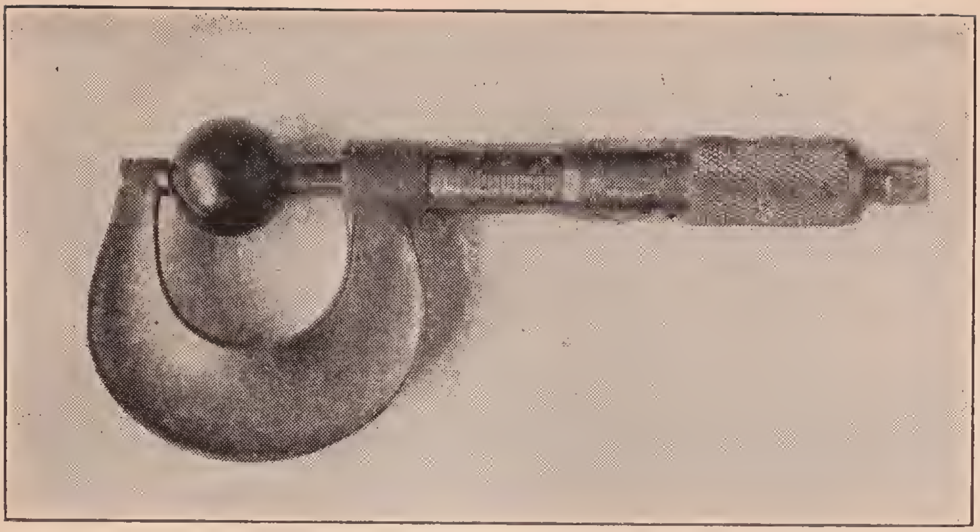
Turn the head or cap through exactly four revolutions and note how far the edge of the circular scale has moved along the linear scale. Record the distance the screw moves during one revolution as the pitch of the screw.

Count the number of divisions in the circular scale. How far does the screw move lengthwise when the cap is moved through one division of the circular scale? Record this as the least count of the instrument.

Set the instrument so that it will read successively: 5.00 mm., 5.01, 5.15, 5.50, 5.55, 5.75, mm. Now set it to read 11.675 mm., and submit it to the instructor for examination.

Close the instrument and note if the zero line of the circular scale coincides with the line running lengthwise of the hub. If not, record the reading as a zero reading and make proper allowance for it in all readings. If the zero reading is to be added, it should be recorded as positive; if to be subtracted, negative.

Determine the diameter of the wire (B. & S. gauge, No. 20) at three different points along the wire and record the average. In a like manner determine the diameter of the sphere and compute its volume.



TABULATION

Pitch of the screw	....
No. of divisions in circular scale	....
Least count of the micrometer	....
Zero reading of micrometer	....
Reading with wire No. 20	....
Diameter of wire No. 20	....
Reading with sphere	....
Diameter of sphere	....
Volume of sphere in cu. cm.	....

OPTIONAL

Change the diameter of the wire into inches and express as so many thousandths of an inch or mils. Consult copper-wire table and find the diameter in mils of copper wire B. & S. gauge, No. 20. Such a table may be found in your text under the subject of Electrical Resistance, or in the Appendix of Manual.

Experiment 4 — DENSITY — ENGLISH UNITS

Density of Wood

Measure the three dimensions of the block of wood using the vernier caliper. Change the fractions of the inch to the decimal form and express to the second place.

To weigh the block use the spring balance (18 oz. capacity). Hang the balance from a spike clamped to a vertical support rod. Before reading a spring balance, give the mass to be weighed a slight up-and-down vibration two or three times and note if the pointer comes to rest at the same position. Note that by estimating to a half division, the balance can be read to the tenth of an ounce.

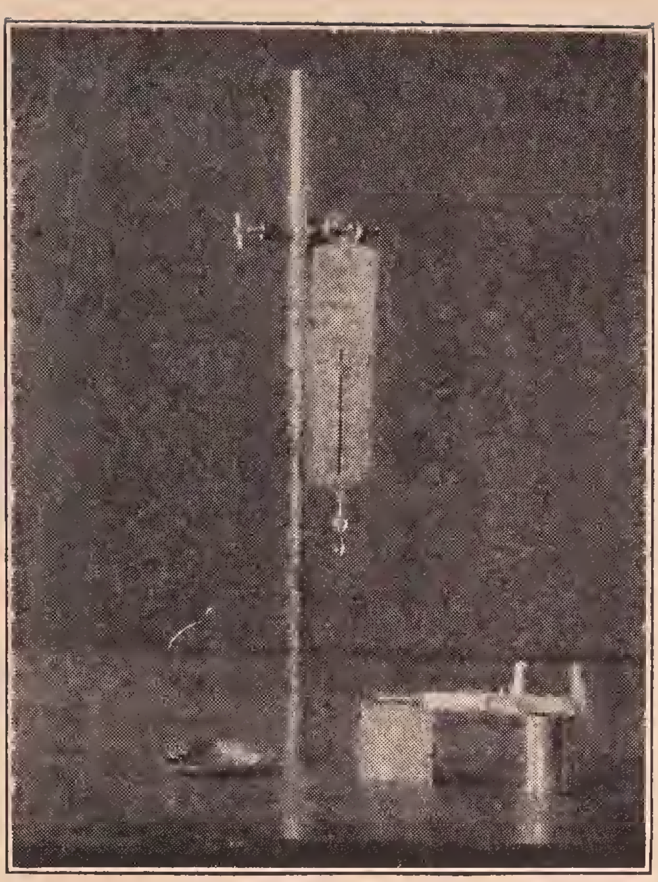
Determine the volume of the block and compute the density of wood in ounces per cubic inch and in pounds per cubic inch.

Density of Water

Measure the inside diameter of the cylindrical vessel using the inside jaws of the caliper. To measure the depth of the vessel use the extension or depth gauge of the caliper.

Fill the vessel level-full of water and weigh on the spring balance.

Determine the volume of the vessel and compute the density of water in ounces per cubic inch and in pounds per cubic inch.



TABULATION

WOOD

Length of block	.... in.
Width of block	.... in.
Thickness of block	.... in.
Weight of block	.... oz.
Volume of block	.... cu. in.
Density of wood	.... oz. per cu. in.
Density of wood	.... lb. per cu. in.

WATER

Diameter of vessel	.... in.
Depth of vessel	.... in.
Weight of water	.... oz.
Volume of water	.... cu. in.
Density of water	.... oz. per cu. in.
Density of water	.... lb. per cu. in.

OPTIONAL

Weigh five fluid ounces of water and compute the volume in cubic inches of a fluid ounce.

Weigh a half of a measuring cup of water and compute the volume in cubic inches of a measuring cup.

Experiment 5 — DENSITY — METRIC UNITS

Density of Wood

Measure the three dimensions of the block of wood using the vernier caliper. Record readings in centimeters.

To weigh the block use the platform balance. When using the balance, observe the following rules:

(*a*) Move the slider on the graduated horizontal bar so that the left edge is on the zero line and note if the pointer comes to rest at the central line of the scale or, better, if it swings the same number of divisions on each side of the central line.

(*b*) Always place the object to be weighed on the left-hand pan.

(*c*) In placing known weights on the right-hand pan, try the weights in consecutive order beginning with a large weight. Do not use weights smaller than the five gram.

(*d*) Make the final balance by moving the slider to the right. Read the grams and tenths of grams on the bar and add to the weight on the pan.

(*e*) Never leave the weights or object weighed on the pans for any length of time after the weight is recorded.

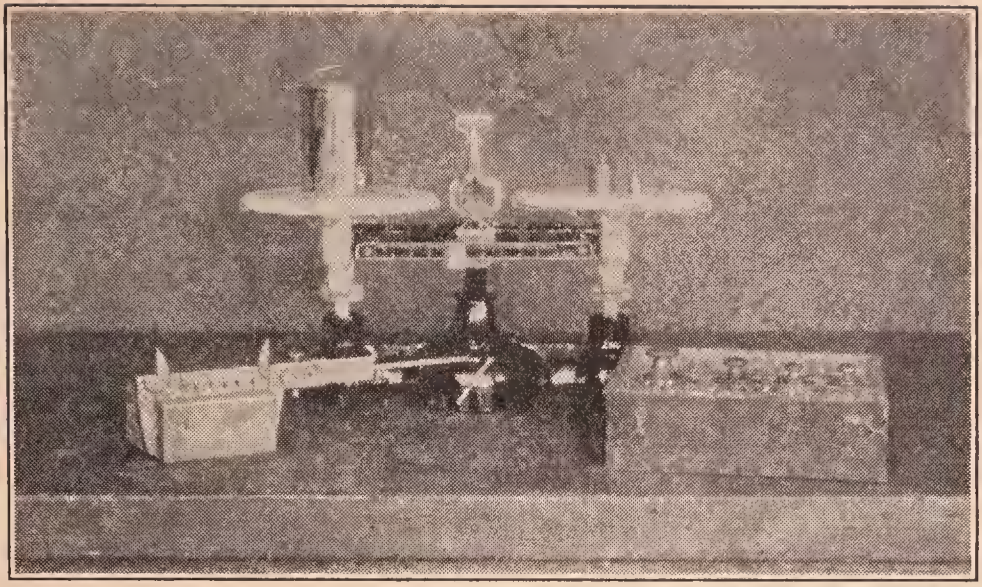
Determine the volume of the block and compute the density of wood in grams per cubic centimeter.

Density of Water

Measure the inside diameter of the cylindrical vessel using the inside jaws of the caliper. To measure the depth of the vessel, use the extension or depth gauge of the caliper.

Fill the vessel level-full of water and weigh on the platform balance.

Determine the volume of the vessel and compute the density of water in grams per cubic centimeter and in kilograms per liter.



Tabulation

Wood

Length of block	.... cm.
Width of block	.... cm.
Thickness of block	.... cm.
Weight of block	.... gm.
Volume of block	.... cu. cm.
Density of wood	.... gm. per cu. cm.

Water

Diameter of vessel	.... cm.
Depth of vessel	.... cm.
Weight of water	.... gm.
Volume of water	.... cu. cm.
Density of water	.... gm. per cu. cm.
Density of water	.... kgm. per liter

Optional

Determine the weight of a *level* teaspoonful, dessertspoonful, and tablespoonful of dry salt. Compute the number of teaspoons in a dessertspoon and in a tablespoon.

When weighing a substance like salt, place it on a filter paper. A second filter paper should be placed on the weight pan.

Experiment 6 — LEVERS AND MOMENTS

First Test: Fulcrum between Forces

Place a wire nail through hole in center of a half-meter stick and clamp to a vertical support at a point six or eight inches above the table.

Determine and record in ounces the weight of the two masses. Use a 64 oz. capacity spring balance and two and four pound masses.

By means of a loop of thread suspend the smaller mass near the right-hand end of the stick and suspend the larger mass on the left at a point at which it will exactly balance the mass on the right.

Record the distances and weights and compute the moment of each force. The perpendicular distance from the line of action of a force to the fulcrum is called the arm of the force.

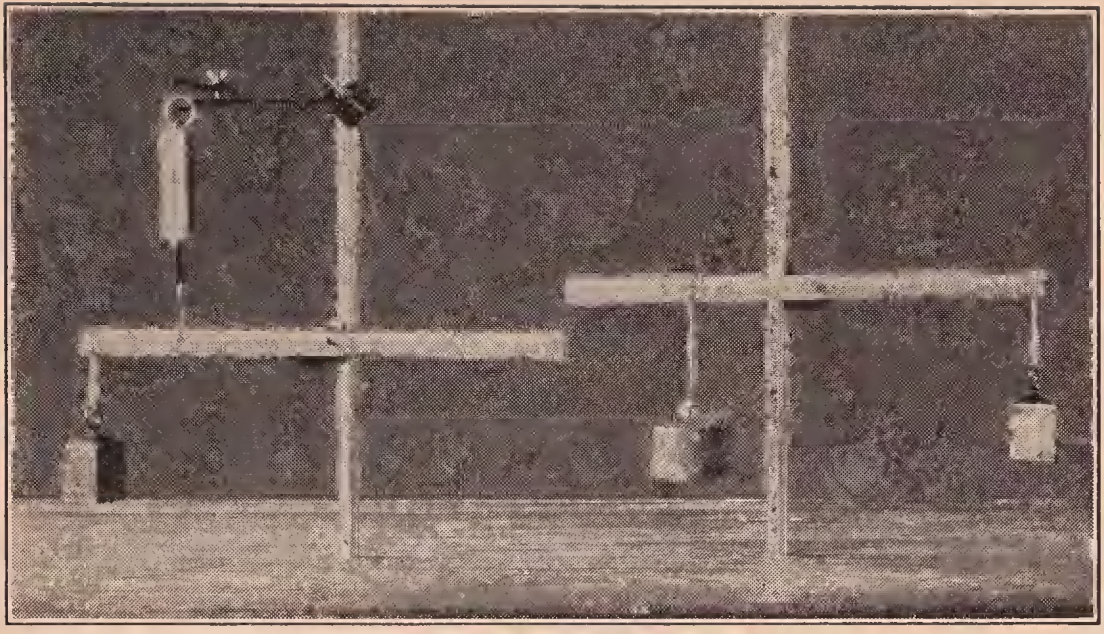
Second Test: Weight between Fulcrum and Pull

Attach the spring balance to the hole near one end of the stick and suspend the larger mass at some point between the balance and the fulcrum. Read the balance when the stick is horizontal.

Record the forces and their arms and compute the moment of each force. The weight lifted or the force exerted by a machine is called the resistance and the pull or the force applied to a machine is called the effort.

Third Test: Effort between Fulcrum and Resistance

Suspend the smaller mass at a point near one end of the stick and hook the balance in the hole nearly midway between the fulcrum and the end of the stick. Read the balance when the stick is horizontal. Record all forces and compute the moment of each force.



Tabulation

First Test:	Weight of large mass	....
	Weight of small mass	....
	Arm of large force	....
	Arm of small force	....
	Moment of large force	....
	Moment of small force	....
Second Test:	Weight used (resistance)	....
	Balance reading (effort)	....
	Resistance arm	....
	Effort arm	....
	Moment of resistance	....
	Moment of effort	....
Third Test:	Weight used	....
	Balance reading	....
	Resistance arm	....
	Effort arm	....
	Moment of resistance	....
	Moment of effort	....

Optional

Repeat the second test suspending both masses, at two different points, between the balance and the fulcrum. Record forces and arms on a diagram and compute the moments of all forces involved. What relation of moments can be expressed?

Experiment 7 — PARALLEL FORCES

Part A

Weigh three different size masses (one, two and four pound) to the nearest ounce. Use a spring balance of 64 oz. capacity.

Clamp a small rod at right angles to the vertical support rod. Place two spring balances on the bar and suspend a half-meter stick from the hooks in such a manner that the balances will be parallel and some distance apart.

In order to eliminate the weight of the bar, read each balance and record as the "zero reading." These readings are to be subtracted from subsequent readings of the balances when measuring forces.

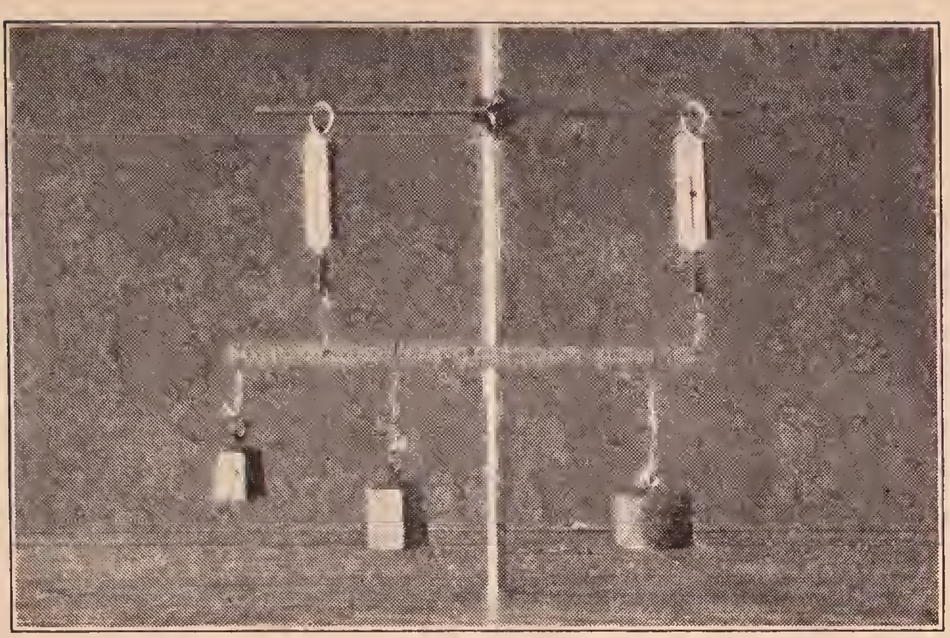
Suspend the three masses from the stick at such positions that the stick will be exactly horizontal. Record the forces upward at the balances. What relation is seen between the total upward and the total downward forces?

Part B

With the apparatus as balanced in A, select any point you wish along the stick as the fulcrum. Measure the distance from the point of application of each force to the point selected as the fulcrum and record as the arm of that force.

Compute the moment of each force. If the force tends to produce clockwise rotation around the selected point, record it as a positive moment. If counterclockwise, record it as a negative moment.

What general principles can be stated concerning the fulcrum and moments of parallel forces?



Tabulation

Part A

Weight of large mass	.... oz.
Weight of medium mass	.... oz.
Weight of small mass	.... oz.
Upward force, right balance	.... oz.
Upward force, left balance	.... oz.
Total downward force	.... oz.
Total upward force	.... oz.

Part B

Point selected as fulcrum		....
Arm of large mass		.... cm.
Arm of medium mass		.... cm.
Arm of small mass		.... cm.
Arm of right balance		.... cm.
Arm of left balance		.... cm.
Moment of large mass	+ or −	.... oz. cm.
Moment of medium mass	+ or −	.... oz. cm.
Moment of small mass	+ or −	.... oz. cm.
Moment of right balance	+ or −	.... oz. cm.
Moment of left balance	+ or −	.... oz. cm.
Sum of positive moments		.... oz. cm.
Sum of negative moments		.... oz. cm.

Optional

A bridge 60 feet long weighs 20 tons and has its center of gravity at the center. A six-ton truck stands with its center of gravity 15 feet from the north end. Find the total weight supported at each end of the bridge.

Part I

Weigh the half-meter stick on a platform balance to the nearest tenth of a gram. (As most of the sticks weigh between 70 and 80 grams, a quick determination can be made by placing 70 grams on the right-hand pan and using the beam and rider to complete the balance.)

Find the center of mass or the center of gravity by balancing it on a prism. The stick may be considered balanced when it will remain with either end down. Read to the millimeter and record as the location of the center of gravity.

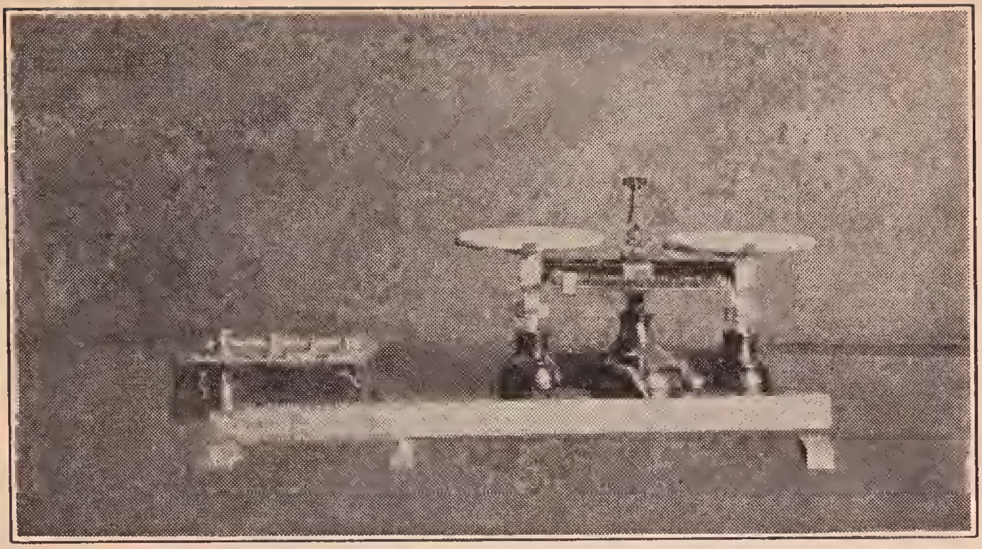
Place a 50-gram weight on the stick so that its center will be over a line one centimeter from the end, and without the use of any other weights place the stick on the prism in such a position that it will be in equilibrium. The edge of the prism should be at right angles to the stick.

Measure carefully and record the distance from the fulcrum to the center of the weight and from the fulcrum to the center of gravity of the stick. Compute the moment of the weight. If the weight of the whole stick were to act as a single force with its point of application at the center of gravity, compute its moment and record as the moment of the stick.

What relation is found between the moment of the weight and the moment of the stick? What definition does this relation suggest for the center of gravity?

Part II

Repeat the experiment using a brass cylinder of unknown weight in place of the 50-gram mass. From the relation of moments discovered in Part I, compute the weight of the cylinder. Determine the correct weight of the cylinder by using the platform balance. Record the number of the cylinder.



Tabulation

Part I

Location of center of gravity	.... cm.
Weight used	.... gm.
Distance (weight to fulcrum)	.... cm.
Weight of stick	.... gm.
Distance (fulcrum to center of gravity)	.... cm.
Moment of weight	.... gm. cm.
Moment of stick	.... gm. cm.

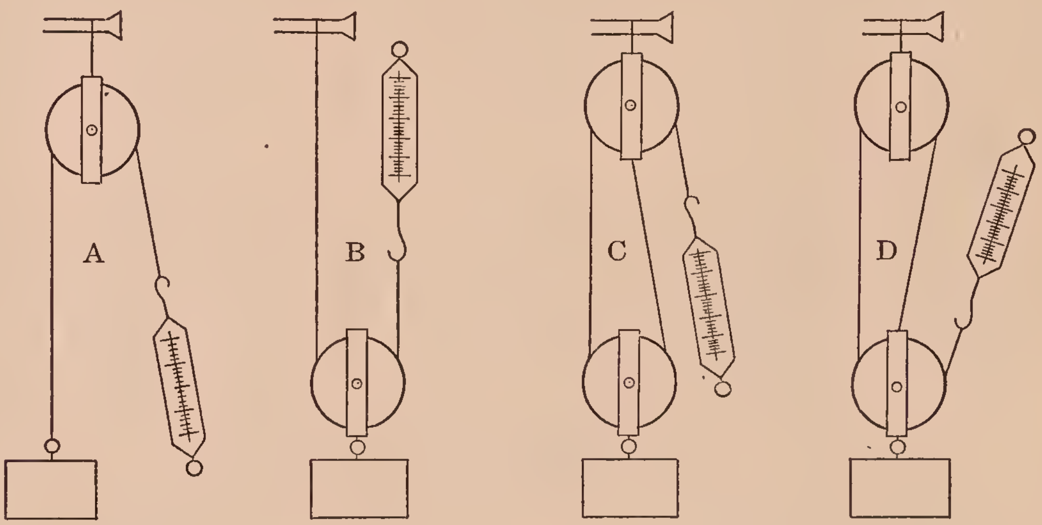
Part II

Number of cylinder	....
Distance (cylinder to fulcrum)	.... cm.
Distance (fulcrum to center of gravity)	.... cm.
Moment of stick	.... gm. cm.
Moment of cylinder	.... gm. cm.
Weight of cylinder (computed)	.... gm.
Weight of cylinder (weighed)	.... gm.

Optional

Place the 20-gram weight one centimeter from one end of the stick and the 50-gram weight one centimeter from the other end. With the weights thus placed balance the stick on the prism and show that the moments are still equal. Draw a diagram and record on the diagram the forces and distances.

A spring balance is made to read correctly in a vertical position with the hook downward. When the balance is used inverted, a correction must be made. To determine the correction place the hooks of two spring balances together and clamp to the support rod so that one balance will be inverted and the other in correct position. Adjust a clamp so that the balances will read near center of scale. Determine what correction must be made on the inverted balance to make reading correct, or same as the upper balance.



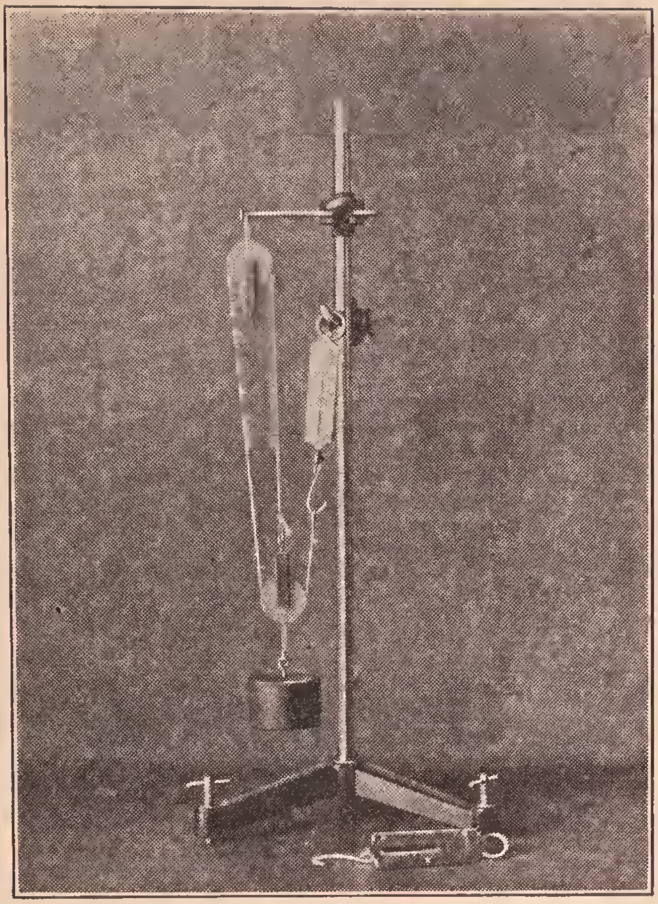
(*a*). Arrange the apparatus as shown in A. The lower clamp should be so adjusted that the weight will be lifted from the table. Record the corrected balance reading as the pull (P) necessary to support the weight (W).

Note and record as (N) the number of sections of the cord that are helping to support W; that is, the number of cords passing to and from the weight. Determine the weight of the iron mass and record as W. Calculate the ratio of W to P and express it as a quotient to the second decimal place.

(*b*) Repeat all of (*a*) with apparatus arranged as in B. Note that the pulley or movable block here forms a part of the weight and should be included in W.

(*c*) Repeat all of (*b*) with apparatus as in C.

(*d*) Repeat all of (*b*) with apparatus as in D.



TABULATION

PART	P	W	W ÷ P	N
A	....	....	....	....
B	....	....	....	....
C	....	....	....	....
D	....	....	....	....

What statement can be obtained from a comparison of the last two columns? How can the mechanical advantage of a system of pulleys be determined?

OPTIONAL

Determine by diagram the mechanical advantage of two fixed and three movable pulleys. Also for three fixed and two movable pulleys.

Experiment 10 — INCLINED PLANE

Weigh the car or roller on the platform balance to the nearest gram and record as the resistance force. As the inclined plane is a machine used to raise an object to a different level, the weight of the object moved up the incline is the force exerted by the machine against gravity.

Weigh the pan and cord to the nearest gram. Set the plane at an angle of 25 degrees and in such a position that the pan suspended by the cord over the pulley can rise and fall without touching the edge of the table. Adjust the pulley so that the cord is parallel to the plane.

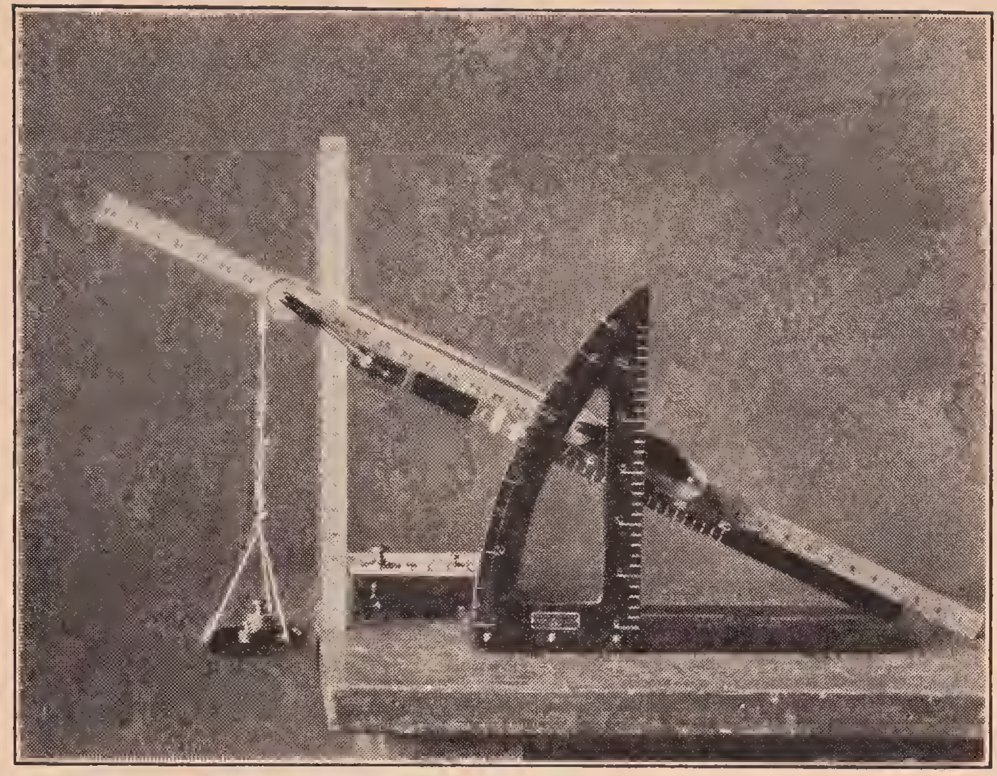
Place the least weight in the pan that will cause the car, once gently started, to continue rolling slowly and uniformly up the incline. Add to this weight the weight of the pan and record as the force necessary to pull the car up the incline, or the theoretical effort plus friction.

To eliminate friction, take off weights until the car will, when gently started, continue to roll slowly and uniformly down the incline. The weight of pan and load is now the force necessary to hold the car on the plane aided by friction. Record as effort minus friction. The average of these two forces would be the effort if there were no friction.

Measure along the incline from the table top to the highest edge of the plane and record as the length of the inclined plane. Measure the perpendicular distance from this edge to the table and record as the height of the plane.

Compute the ratios of the resistance to the effort and the length to the height. Express to the second decimal place.

Compute the work done by the effort to roll the car to the top of the incline (input), and the work done by the resistance against gravity (output). Record the unit in which the work is measured.



Tabulation

Resistance force (R)	....
Weight of pan	....
Effort plus friction	....
Effort minus friction	....
Effort force (E)	....
Length of inclined plane	....
Height of inclined plane	....
Ratio: Resistance to Effort	....
Ratio: Length to Height	....
Input (name of unit)	....
Output (name of unit)	....

State what you have proved to be the mechanical advantage of an inclined plane.

Optional

Determine the grade of the incline used in the experiment.

Note: A Second Method — The board or incline shown in Experiment 14 is used as the inclined plane. For the object to be rolled up the incline use a two-pound mass in a four-wheel car. Use a spring balance to determine the weight of the car and load and the force (effort plus friction) necessary to roll the car uniformly up the incline. Let the car roll uniformly down the incline to determine the effort minus friction.

Experiment 11 — SCREW — AUTOMOBILE JACK

Determine the theoretical mechanical advantage of the screw. When measuring the radius of the circle through which the effort applied to the screw acts, measure from the center of the axis to a point on the end of the handle where the hook of the spring balance is attached. To determine the pitch, measure the distance of ten threads.

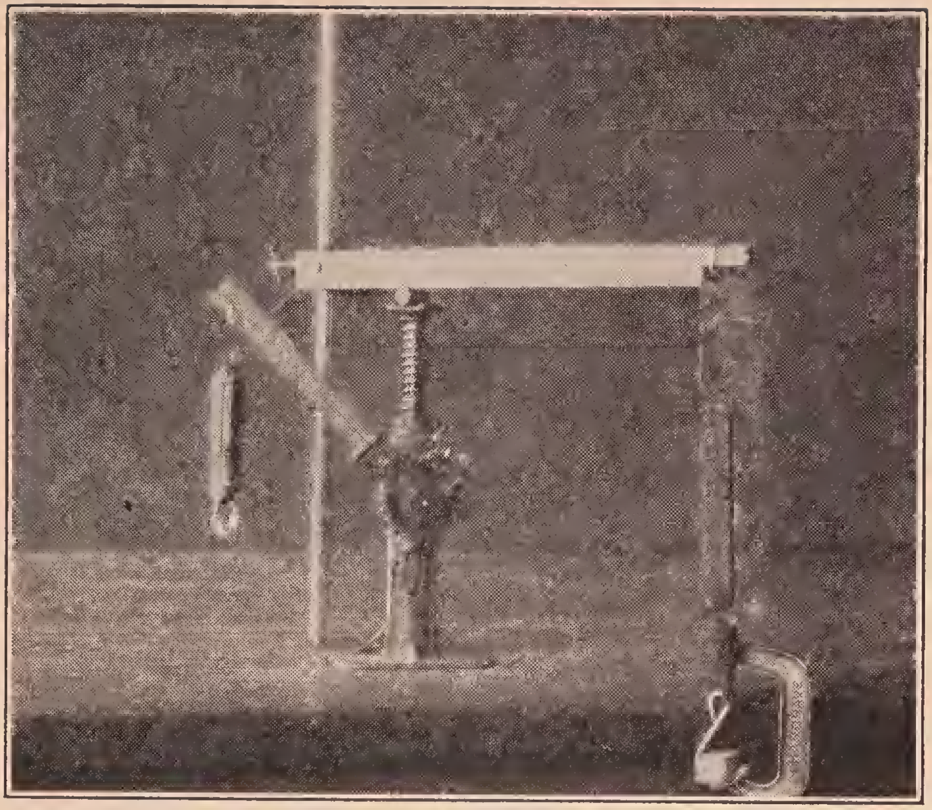
Place a spike in the hole at the end of the lever and clamp to a vertical support rod. On the other end of the lever place a large spring balance (30 lb. capacity) with its hook attached to a block clamped underneath the edge of the table. Place the jack underneath the lever at a point about one-fifth as far from the fulcrum as the large spring balance. Place a small cylinder between the top of the jack and the lever so that the point of application will be definite. Operate the jack until the spring balance reads about twenty-five or thirty pounds.

Attach a smaller spring balance (64 oz. capacity) at the end of the handle and determine the force, at right angles to the handle, necessary to lift the lever. Get a series of five or six readings of this force by watching the balance and note the reading when the handle is moving. Record the average as the effort on the screw.

The record for the large balance should be the average of its readings taken at the beginning and at the end of the series of trials for the effort.

Consider the spike as the fulcrum of the lever. The moment of the force of the large spring balance is then equal to the moment of the force exerted upward on the lever by the jack. Compute the force exerted by the jack and record as the resistance of the jack. From the resistance and effort obtained, compute the actual mechanical advantage of the jack.

Compute the work done by the effort applied to the screw in one rotation of the screw (input). Also the work done by the jack in one rotation (output). Compute the efficiency of the screw.



Tabulation

Length of handle (radius)	....
Pitch of screw	....
Mechanical advantage of screw	....
Reading of small balance (effort)	....
Length of balance arm	....
Length of jack arm	....
Reading of large balance	....
Force exerted by jack (resistance)	....
Mechanical advantage (actual)	....
Work done by effort (input)	....
Work done by resistance (output)	....
Efficiency of automobile jack	....

Optional

Count the number of teeth on the two gear wheels. What effect do these gears have on the theoretical mechanical advantage of the jack? Explain. If the gear wheel on the screw has twice the number of teeth of the other, what then would be the mechanical advantage of the jack?

Experiment 12 — HORSEPOWER — PRONY BRAKE

The horsepower of any producer may be determined by a device known as the Prony brake, one form of which is constructed by placing a belt around the drive wheel and attaching a spring balance to each end of the belt.

As the wheel rotates the difference between the two balances will give the force exerted by the wheel on the belt. This force will be acting each minute through a distance equal to the circumference of the wheel times the number of revolutions per minute. From the force and distance obtained the horsepower can be computed.

Place a short (2 in.) vertical support rod in a receptacle near one end of the table and use as the axle of the large grooved wheel. Place a large washer on the support rod between the table and wheel. (A tripod base clamped to the table may be used in place of the receptacle in the table top.)

Attach the two ends of a short piece of rope to two spring balances of 30 pounds capacity. Place the rope in the groove of the wheel and attach the two spring balances to table clamps on the edge of the table. By moving the clamps along the edge of the table, a varying tension can be placed on the rope.

The student making a test of his power should determine before the test the greatest pull of the balances that he can maintain for one minute with a constant speed of rotation. The speed of rotation is not to exceed one revolution per second. Only one hand is to be used throughout a test.

The student rotating the wheel should count the number of revolutions made during the minute test. A second student should keep time and record the average readings of the two balances during the test.

Make a second trial using the other hand. Each student should make the tests and record only the data of his own trials.

Tabulation

Arm Tested	Right		Left
Reading of first balance	....		....
Reading of second balance	....		....
Force (pull on rope)	....		....
Revolutions per minute	....		....
Circumference of wheel	....		....
Distance (feet per minute)	....		....
Work (foot pounds per minute)	....		....
Total work done		....	
Horsepower		....	

Optional

The "Spirit of St. Louis" was equipped with a 200 horsepower engine. Colonel Lindbergh in his famous trip flew 3610 miles in 33.5 hours. What was the force exerted against the air by the propeller?

Before starting the experiment see that the surface of the board and the surfaces of the block are thoroughly cleaned with sandpaper.

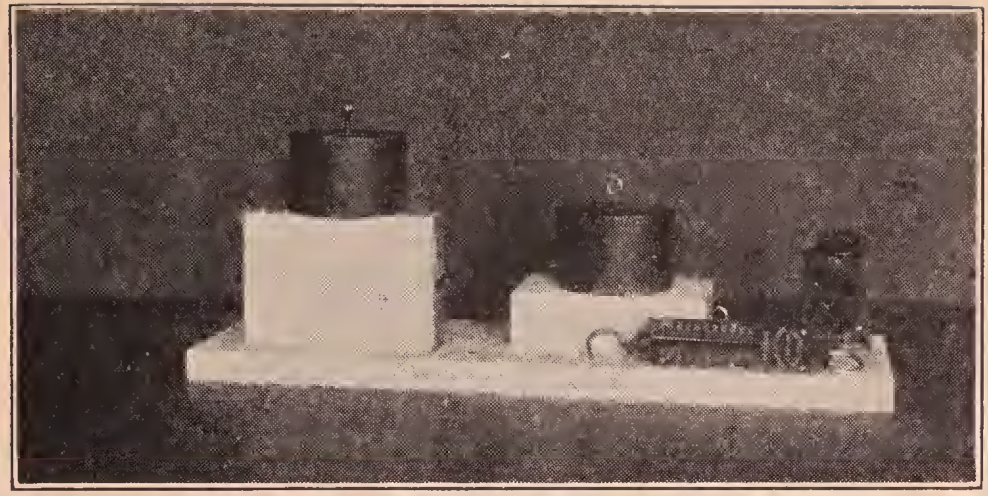
Part A — Coefficient

Friction is measured by measuring the force necessary to overcome it. Place the smaller mass on the block and attach the hook of the spring balance to the hook on the block. Determine the force necessary to start the block (starting friction) and the force necessary to keep the block in slow uniform motion over the top of the board (sliding friction). Several trials should be made before recording any results. Record what seems to be the normal or average reading.

For a second test, place the larger mass on the block. For a third test, use both masses. In each test compute the coefficient of both starting and sliding friction. Express to third decimal place.

Part B — Area of Contact

Using the block and the larger mass determine the force of sliding friction when the block is sliding on its largest surface and when it is turned up and sliding on its edge.



Tabulation

Part A — Coefficient

Trials	1	2	3
Weight of block	....	....	....
Weight on block	....	....	....
Total pressure	....	....	....
Force of friction (starting)	....	....	....
" " " (sliding)	....	....	....
Coefficient of friction (starting)	....	....	....
" " " (sliding)	....	....	....

Part B — Area of Contact

Contact Surface	Side	Edge
Weight of block	....	....
Weight on block	....	....
Total pressure	....	....
Force of friction	....	....
Coefficient of friction	....	....

Optional

What load can a horse working at the rate of one-half horsepower, draw along a level highway at the rate of three miles an hour, if the coefficient of friction between the sled runners and ice covered road is 0.02?

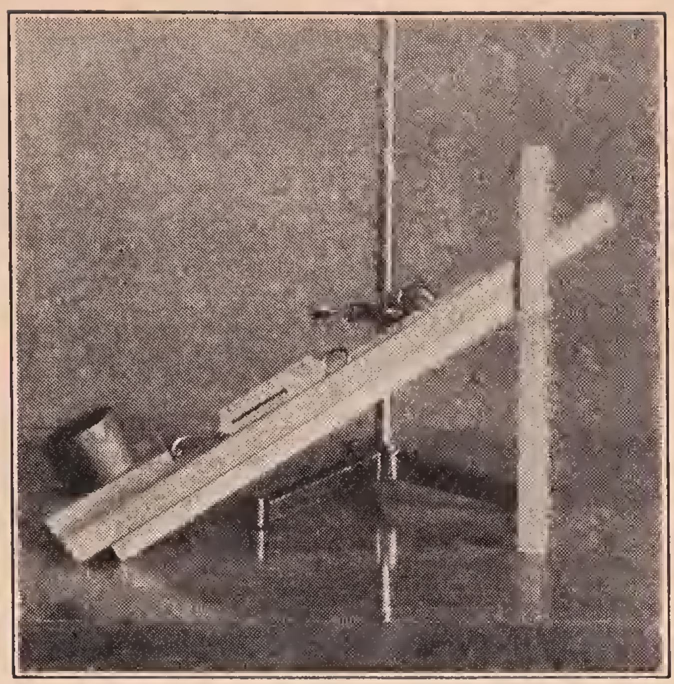
Raise one end of board to form an inclined plane. This can be done by placing one end of nail in the clamp and the other end in hole on edge of board. Adjust the clamp until the lower edge of upper end of board is just six inches above the table.

Measure the length of the inclined plane or the distance from the lower edge to the table along the lower surface of the board. Considering the lower surface of the board as the surface of the inclined plane, measure the base or the distance along the table from the vertex of the plane to a point directly underneath the upper end of the plane.

With the spring balance determine the force necessary to pull the block and iron mass slowly and uniformly up the incline. To prevent the iron mass from slipping, place its ring in the hole of the block.

Make two more tests with the lower edge of the raised end of the board eight and ten inches respectively above the table. Measure the force necessary to overcome friction when the surface is horizontal.

Compute the work done by the machine against gravity (output). Compute the work you did on the machine when sliding the mass the length of the incline (input). To compute the work done against friction multiply the force of the friction, when the surface is horizontal, by the base.



Tabulation

Height of Inclined Plane	Six	Eight	Ten In.
Length of inclined plane	....	....	.... in.
Base of inclined plane	....	....	.... in.
Pull on the incline	....	....	.... oz.
Force of friction (horizontal)	....	....	.... oz.
Weight of block and mass	....	....	.... oz.
Output, total mass × height	....	....	.... in. oz.
Input, pull × length	....	....	.... in. oz.
Work done against friction	....	....	.... in. oz.
Input minus output	....	....	.... in. oz.
Efficiency of inclined plane	....	....	....

Optional

Compute the actual efficiency of the inclined plane in Experiment 10. The input should now be determined when the car is moving up the incline.

Experiment 15 — ARCHIMEDES' PRINCIPLE

Part A — Sinking Object

Determine the buoyant force (apparent loss in weight), on a sinking block when submerged in water. When weighing an object submerged in water, first take the balance reading with the pan submerged.

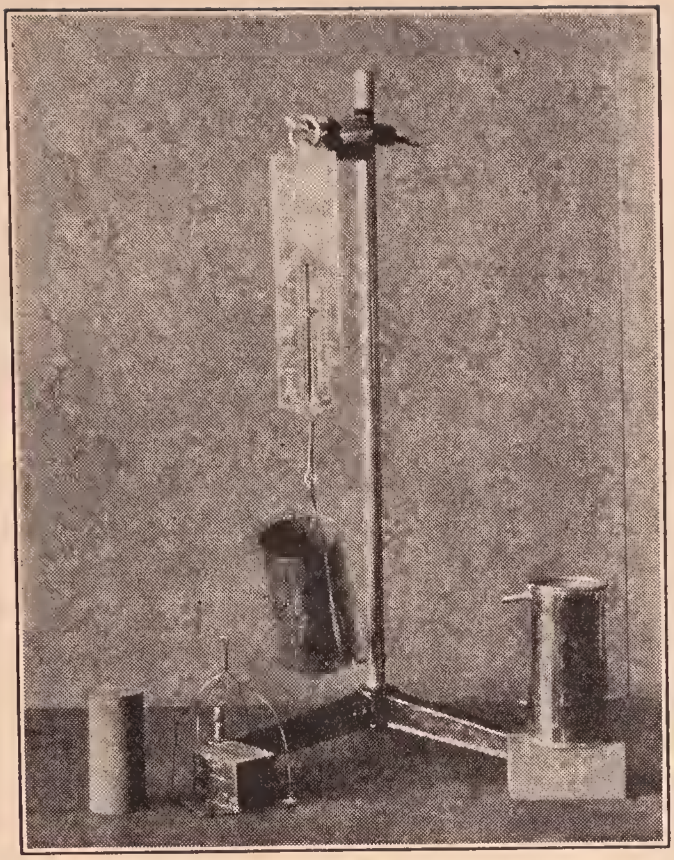
To determine the weight of the water displaced by the block, use an overflow can. To use the overflow vessel properly, place it on a block and pour in water until it is nearly full. Let the excess water flow out of the overflow spout into a catch vessel. Do not disturb the can or touch the end of the overflow spout at any time. Lower the block slowly and carefully into the can and catch the water it displaces in an empty vessel.

Part B — Floating Object

Use the wood cylinder and the overflow can to determine the relation between the weight of a floating object in air and the weight of the water displaced by the object when floating. Care must be taken when lowering the cylinder into the can, that it does not go below its normal floating level.

I. State Archimedes' principle as applied to a sinking object. Explain from your data whether you have proved the principle.

II. State Archimedes' principle as applied to a floating object. Explain whether your results prove the principle.



TABULATION

PART A

Weight of block in air	.... oz.
Weight of block in water	.... oz.
Buoyant force	.... oz.
Weight of catch vessel	.... oz.
Weight of catch vessel and water	.... oz.
Weight of displaced water	.... oz.

PART B

Weight of cylinder in air	.... oz.
Weight of catch vessel	.... oz.
Weight of catch vessel and water	.... oz.
Weight of displaced water	.... oz.

OPTIONAL

A cubical box, three feet in each dimension, floats in water with two-thirds of its volume submerged. When a boy steps on the box it sinks three inches deeper in the water. Find the weight of the boy.

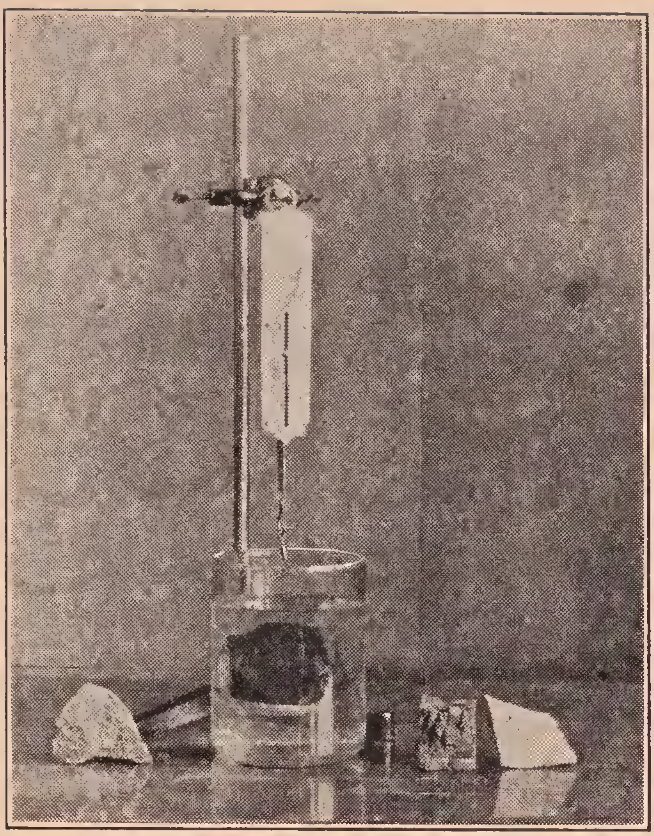
Experiment 16 — SPECIFIC GRAVITY

Part A — Sinking Solids

Determine the specific gravity of three of the following substances: coal, brick, marble, stone. In obtaining the weight of the object when submerged in water, first obtain the reading of the balance when the pan is submerged.

Part B — Floating Solids

Determine the specific gravity of the wood cylinder. To find the weight of an equal volume of water use the overflow can. To entirely submerge the cylinder, press it just below the surface with point of pencil.



Tabulation

Part A

Material	Coal	Brick	Etc.
Weight in air	....	....	....
Weight in water	....	....	....
Weight of equal vol. of water	....	....	....
Specific gravity	....	....	....

Part B

Weight of wood cylinder	....
Weight of catch vessel	....
Weight of vessel and water	....
Weight of equal vol. of water	....
Specific gravity of wood	....

Optional

Determine the specific gravity of a saturated solution of salt by weighing a piece of coal in air, then in the solution and then in water.

Weight of coal in air	....
Weight of coal in solution	....
Weight of coal in water	....
Specific gravity of salt solution	....

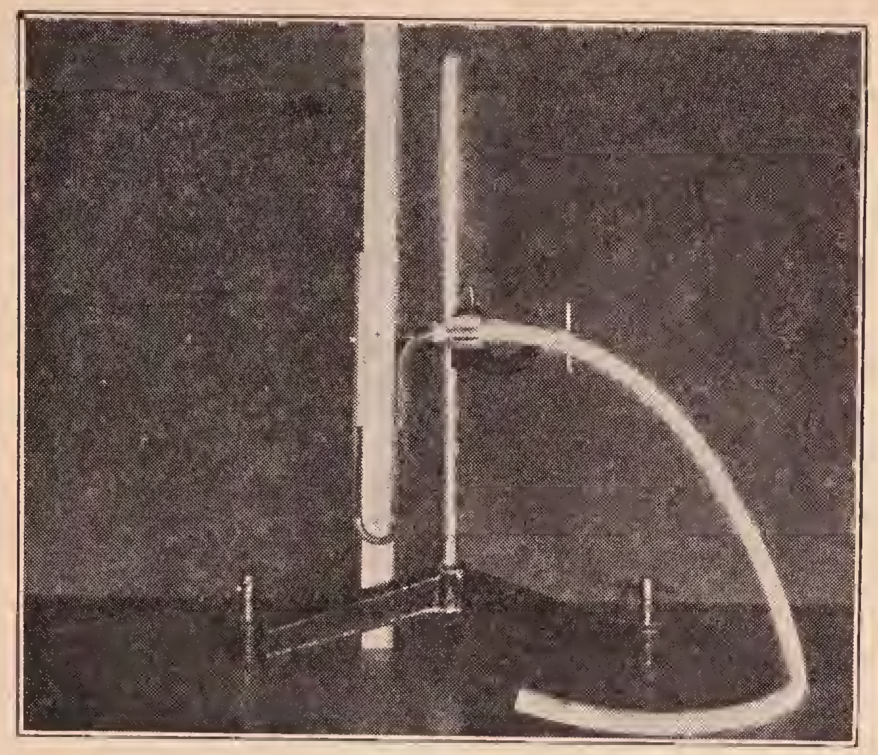
Experiment 17 — OPEN MANOMETER

Gas Pressure

Fill the U-tube or open manometer until the level of the water is at the midpoint of the longer or vertical tube. Clamp the manometer in a vertical position. The clamp should be placed where the rubber tube overlaps the glass tube. Not much pressure at the clamp will then be necessary to hold the tube firmly.

Connect the manometer to the gas-cock and turn on the gas very slowly. Measure the final difference in levels and record as the manometer reading. Compute the pressure of the gas in pounds per square inch.

Read the barometer and compute the pressure of the atmosphere in pounds per square inch. Determine the pressure absolute of the illuminating gas.



Tabulation

Manometer reading	.... in.
Gas pressure	.... lb. per sq. in.
Barometer reading	.... in.
Atmospheric pressure	.... lb. per sq. in.
Gas pressure absolute	.... lb. per sq. in.

Optional

Take all readings in the metric system and determine the following:

Manometer reading	.... cm.
Gas pressure	.... gm. per sq. cm.
Barometer reading	.... cm.
Atmospheric pressure	.... gm. per sq. cm.
Gas pressure absolute	.... gm. per sq. cm.

Read the barometer in inches and compute the atmospheric pressure in pounds per square inch. Record it as the initial pressure (P) or pressure on the enclosed air.

Place water in the U-shaped glass tube so that, when held in the vertical position with closed end upward, the water will be at the same level in each tube and about two inches above the lower point of the tube. This can be done by pouring slowly a small quantity of water in the tube and then inverting the tube in such a manner that some of the water will pass around the bend into the closed end.

Repeat the process until the water is about two inches high in the tube. Then hold the tube vertically with closed end up and pour in water until the levels are the same.

Slip the open end of the tube about one inch into the rubber tubing and clamp in a vertical position. Be sure to place the clamp where the rubber tubing overlaps the glass tube.

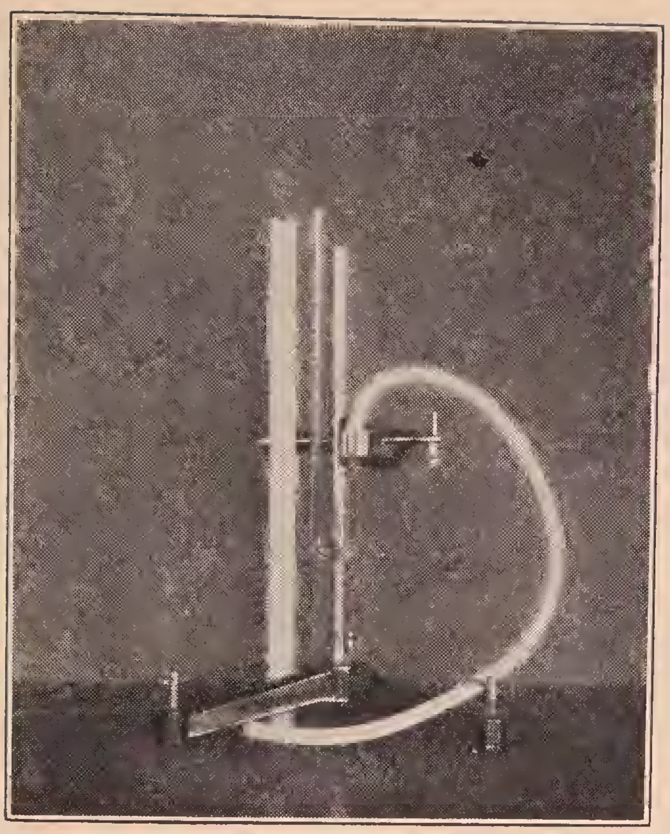
Measure in inches the length of the enclosed air column and record as the initial volume of air (V).

Blow through the rubber tube and see how high you can force the water in the tube. *Do not place the tube in the mouth.* Place the tube in your closed fist and press your lips against the thumb and forefinger. Record the length of the resulting column of air as the resulting volume (v).

From the initial pressure (P), the initial volume (V), and the resulting volume (v) compute the resulting pressure on the enclosed air. (Boyle's Law.)

The pressure from the lungs is not only compressing the air in the tube, but it is supporting the column of water in the closed tube. From the difference of levels compute this extra pressure.

Record the total pressure as the pressure absolute. From the atmospheric pressure and the pressure absolute compute the lung pressure.



Tabulation

Barometer reading	.... in.
Pressure on air, P	.... lb. per sq. in.
Volume of air, V	.... in. sections
Resulting volume, v	.... in. sections
Resulting pressure, p	.... lb. per sq. in.
Dif. of water levels	.... in.
Pres. of water column	.... lb. per sq. in.
Pressure absolute	.... lb. per sq. in.
Lung pressure	.... lb. per sq. in.

Optional

Repeat the experiment and record all readings in the metric system. Determine the lung pressure in grams per square centimeter.

Clamp the meter stick to the vertical support rod so that it will be horizontal and about one foot above the top of the table. See that the rod is rigid in the receptacle.

Suspend the pan ten centimeters from the outer end of the meter stick. Hold a ruler in a vertical position and record in millimeters the exact distance from the table to the upper edge of the end of the stick as the zero reading.

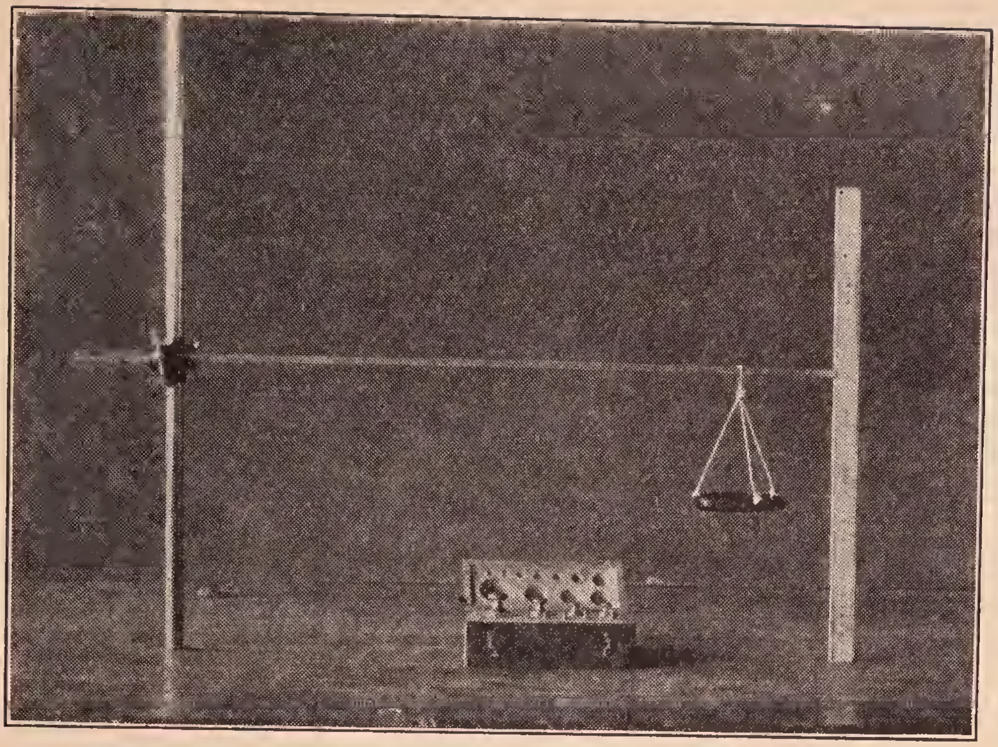
Place a 50-gram mass in the pan and again record the distance to the table. Repeat using the following masses: 100, 150, 200, 250, 300, 350, 400 grams. Note and record the zero reading each time before placing a new mass on the pan.

From your data compute the total bend produced by each weight or force. Also determine the ratio of the total bend to the force producing it in each trial. Express the ratio as a quotient to the second decimal place.

What terms may be applied to the weight in the pan and to the bend or deflection produced?

From the last column what statement can be made concerning the relation of deflection and weight?

If the zero reading remains constant what does it signify?



Tabulation

Weight in Pan	Zero Reading	Reading with Wt.	Total Bend	Ratio Bend ÷ Wt.
50 gm.	....	....	....	....
100 gm.	....	....	....	....
150 gm.	....	....	....	....
200 gm.	....	....	....	....
250 gm.	....	....	....	....
300 gm.	....	....	....	....
350 gm.	....	....	....	....
400 gm.	....	....	....	....

Optional

Using weights and deflections as coördinates, plot a curve showing the relation between the two. If coördinate or cross-section paper is not used, carefully rule a portion of one page of your notebook.

Fasten the ring of a large spring balance, 30 lb. capacity, near the edge of the table by means of a clamp.

Cut a piece of copper wire No. 26, ten or twelve inches long. CAUTION: When cutting wire from a spool, to prevent the wire from unwinding and getting tangled, unwrap the end of the wire from the tack, unwind from the spool the length of wire needed, wrap once around the tack and then cut from the free end.

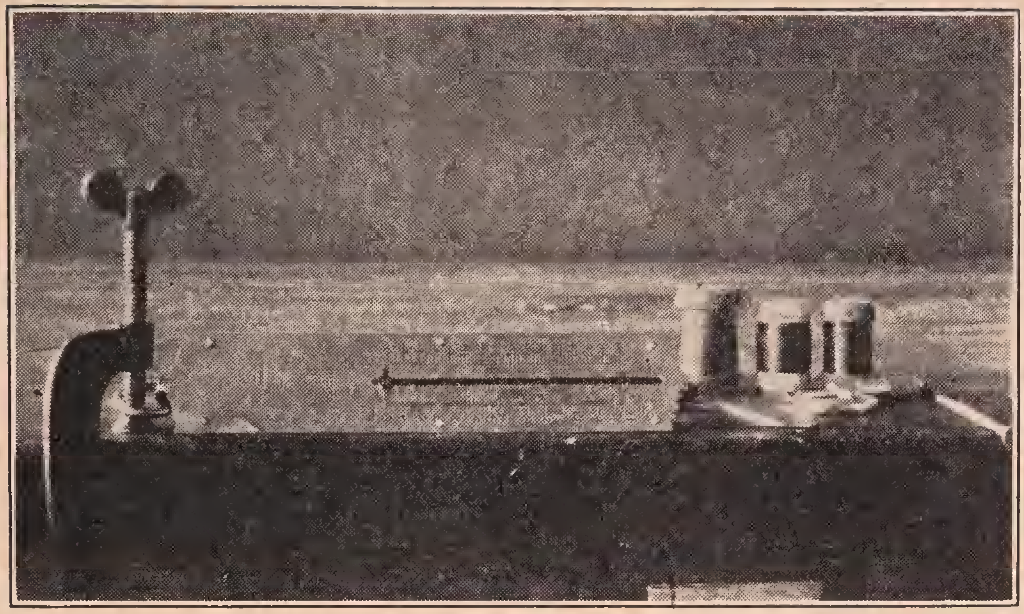
Fasten one end of the wire firmly to the hook of the spring balance and the other end to a large spike.

Two students should now work together, one to pull on the wire and the other to read the balance. The force of the pull should be increased *very slowly* so that the balance can be read at all times and the exact position of the pointer noted when the break occurs.

In a like manner determine the breaking strength of a brass wire No. 32 and an iron wire No. 32.

With a micrometer screw measure the diameter of each wire. Change the reading to inches and compute the cross-section area of the wire in square inches.

From the force necessary to break the wire and the cross-section area, compute the tensile strength or the force necessary to break a wire one square inch in cross-section.



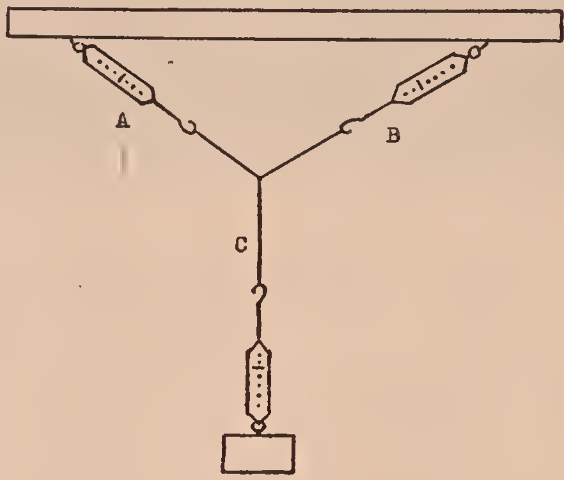
TABULATION

MATERIAL IN WIRE	COPPER	BRASS	IRON
Gauge number of wire	....	....	....
Zero reading of screw	....	....	....
Diameter in millimeters	....	....	....
Diameter in inches	....	....	....
Cross-section in sq. in.	....	....	....
Reading of balance	....	....	....
Tensile strength	....	....	....

OPTIONAL

The Brooklyn Bridge is supported by four cables. Each cable is made up of 6300 steel wires, No. 7 gauge. The tensile strength of steel is 300,000 pounds per square inch. Compute the total breaking strength and express in tons.

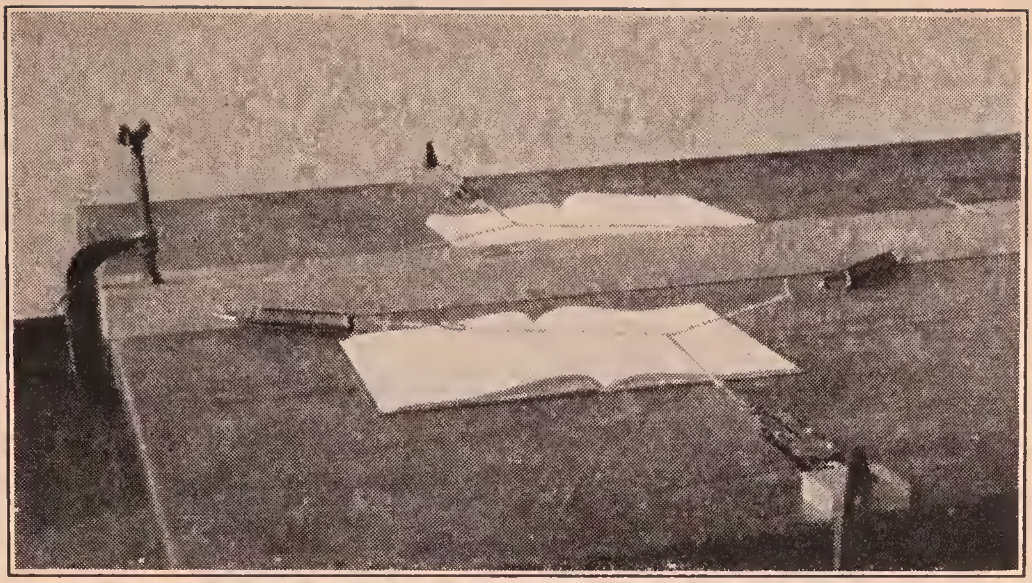
Connect the three balances as shown in the diagram. Balances A and B are connected to hooks at center of table, balance C to the block clamped to the edge of the table. Adjust clamp and cords so that the balances will read between 50 and 60 ounces. It is better not to have any two balances read the same.



Place the open notebook on the table so that the center of the right-hand page will be under the junction of the cords. Draw lines that will represent the projection of the three cords on the page. Record near each line the tension or force on the cord.

Represent the junction of the cords by O. Let one millimeter represent one ounce of force and lay off from O on each of the three lines a distance that will represent the magnitude of the force. Call these distances OA, OB, and OC.

With any two of these lines as sides complete a parallelogram by using ruler and compass. Draw the diagonal from O, measure its length, and record near it the magnitude of force it represents.



Tabulation

Reading of balance A	....
Reading of balance B	....
Reading of balance C	....
Length of side ( )	....
Length of side ( )	....
Length of diagonal OD	....
Magnitude of resultant	....
Magnitude of equilibrant	....

If two of the forces were replaced by a single force that would have the same result, it would need to be equal and in opposite direction to the third force. If the force found by the diagonal is equal to the third force, what does the experiment prove?

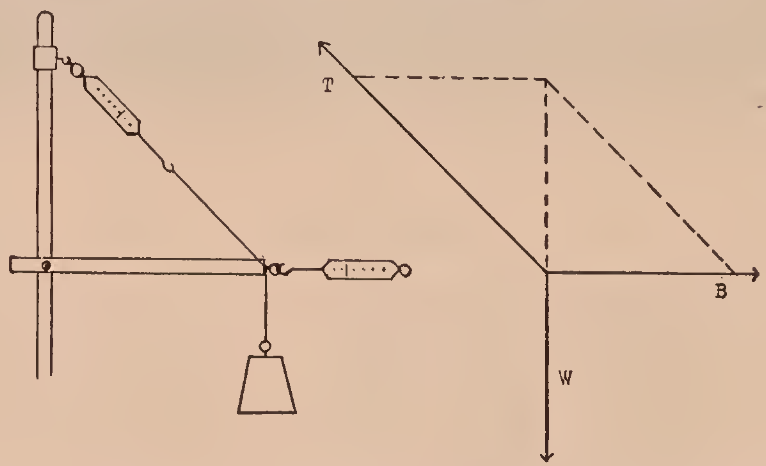
Optional

Will the pull on the hammock hooks be increased or decreased if they are put farther apart at the same height, the person in the hammock being consequently higher from the ground? Prove your answer by means of diagrams.

Experiment 22 — SIMPLE CRANE

A good illustration of the resolution of a force is found in the simple crane or when a weight is hung out on a bracket from a pole. The beam is spoken of as the "boom" and the connection from the outer end of the boom to a higher point on the pole as the "tie."

The weight, a single vertical force, is resolved into two effective component forces: One is a tension in the tie rope, the other a thrust of the boom against the pole.



Part I — Components Determined by Experiment

Weigh the iron mass in ounces. Use the half-meter stick as the boom and connect to the support rod by placing the nail through the large hole. Before attaching the tie rope and the weight to the end of the boom, find the pull downward on the outer end of the boom due to its own weight. Add this to the weight of the iron mass.

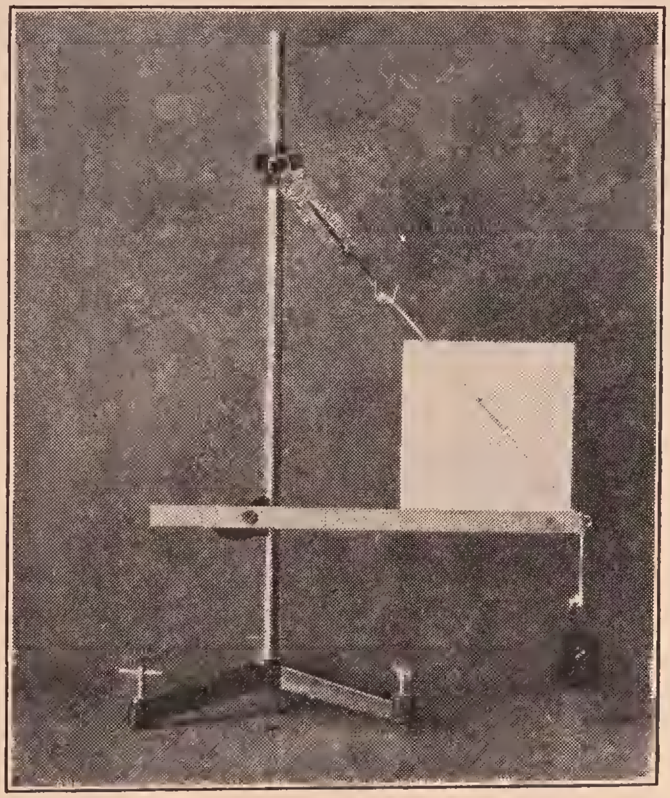
Attach the tie rope and the weight to the outer end of the boom. Adjust the upper clamp until the boom is horizontal. Read the balance in ounces and record as the tie tension. To obtain the thrust of the boom against the support rod, hook a second spring balance to the screw eye in the end of the boom and pull outward until the stick just leaves the nail. This condition can be easily detected if that end of the stick rests lightly in the other hand.

Part II — Components Determined by Parallelogram of Forces

Measure with the protractor the angle between the boom and the tie rope. On the left-hand page of the notebook

draw three lines that will represent the directions of the three forces; weight, tie, and boom thrust outward.

Extend the weight line vertically upward a distance to represent the weight. Let two millimeters represent one ounce of force. With this line as a diagonal, complete the parallelogram. Measure the sides representing the tie and thrust force and express in ounces.



TABULATION

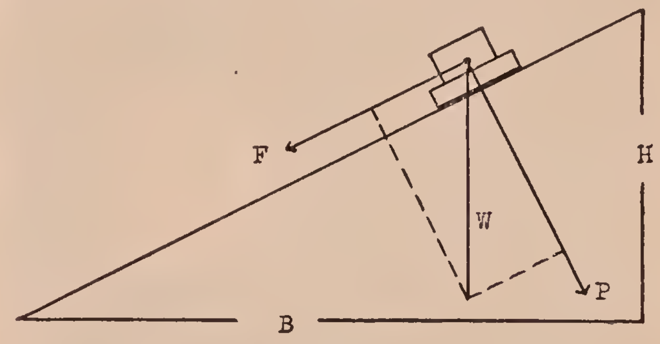
Weight on end of boom	.... oz.
Tie tension by experiment	.... oz.
Boom thrust by experiment	.... oz.
Angle between tie and boom	.... degrees
Angle between boom and weight line	.... degrees
Length of diagonal	.... mm.
Length of tie side	.... mm.
Length of thrust side	.... mm.
Tie tension by construction	.... oz.
Boom thrust by construction	.... oz.

OPTIONAL

Raise the upper clamp on the support rod so that the boom is about 30 degrees to the horizontal and make a second test and parallelogram.

When a body rests on an inclined plane, its weight which is a vertical force is resolved into two effective component forces. One of these effects is pressure on the plane, hence a force perpendicular to the plane. The other tends to produce motion down the plane, hence a force parallel to the plane.

If the plane is placed at such an angle that the tendency to slide is just balanced by the force of friction, then by definition the ratio of the parallel force (friction) to the perpendicular force (pressure) is the coefficient of friction.



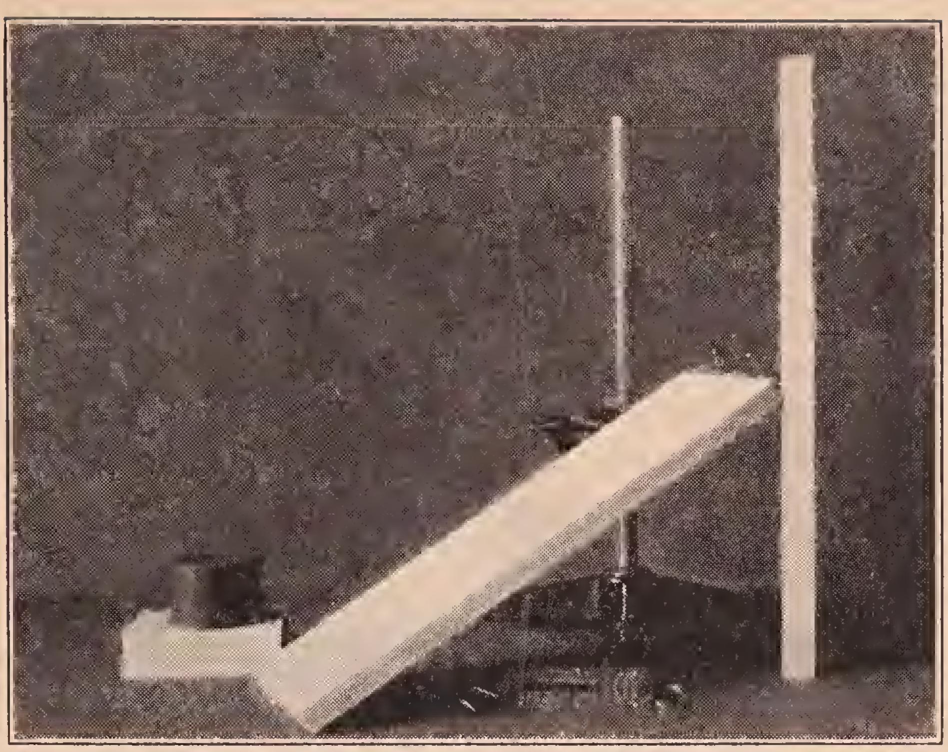
By similar triangles it will be seen that the friction force is to the pressure force as the height of the inclined plane is to the base. The coefficient of friction can therefore be determined by dividing the height by the base.

Part I — Coefficient of Friction by Definition

Weigh the block and iron mass in ounces. Place them on the board when in a horizontal position and find the force of sliding friction as in a previous experiment. Compute the coefficient of friction.

Part II — Coefficient of Friction by Resolution of Forces

Raise and clamp the board in such a position that the block and iron mass will just slide down with uniform motion if the board is constantly tapped lightly with the finger. The angle of the plane is now called the limiting angle of friction. Considering the lower surface of the board as the length of the inclined plane, measure the height and base and compute the coefficient of friction.



Tabulation

Weight of block and iron	.... oz.
Force of sliding friction	.... oz.
Coefficient of friction	....
Height of inclined plane	.... in.
Base of inclined plane	.... in.
Ratio of height to base	....

Optional

Coefficient of Friction by Construction of Parallelogram

By means of a protractor measure the limiting angle of friction. Construct a right-angle parallelogram of forces by using the total weight as the diagonal and the angle of the plane as the angle between diagonal and one side. (Let two millimeters represent one ounce of force.) Determine the magnitude of the two forces represented by the sides of the parallelogram. Compute the coefficient of friction. Record lengths and magnitude of forces represented on the drawing.

Place the acceleration apparatus or grooved plank on the table in a horizontal position with the grooved surface upward. Release the steel ball at the edge of the groove and observe that it rolls from one side to the other, like the movement of a pendulum, in equal periods of time.

Raise one end of the plank 10 or 20 centimeters from the table. Release the ball at the center of the upper end of the groove and observe that it rolls down with increasing speed. Since the force causing the ball to roll is a constant component of gravity, it must roll with uniformly accelerated motion.

While the plank is inclined, release the ball at the edge of the upper end. It should be released when placed against the upper surface of the guide so that it will not start to roll down the incline until it has reached the center of the groove. Observe in this trial that it has a combination of the first two motions and that the side movement may be used as a means of determining how far the ball rolls down the incline in equal periods of time.

Wipe the grooved surface with a damp cloth and then rub it thoroughly dry. Cover the groove with a thin and uniform sifting of lycopodium dust. Raise the end of the plank by means of blocks, 20 centimeters above the table. Carefully release the ball at the edge above the guide. Blow away the powder very carefully and the dust showing the path of the rolling ball will remain on the plank. Place the meter stick on its edge in the groove so that its metric surface will be over the exact center of the groove. Record the total distance the ball rolled at the end of each period. Compute and record the distance rolled each individual period.

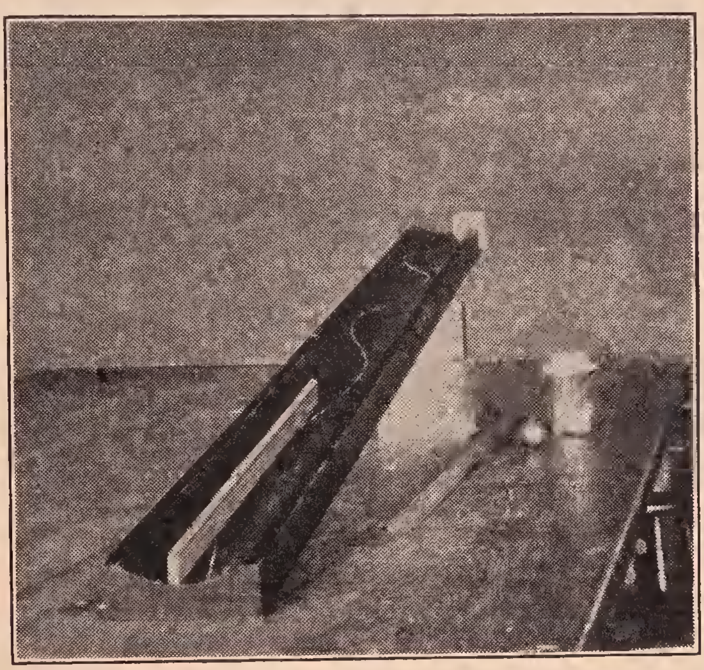
Compute the speed of the ball at the end of each period by the formula: average speed = one-half of the initial speed (zero) plus the final speed (X); or, final speed = two times the average speed. To find the average speed during any number of periods, divide the total distance that the ball rolls by the number of periods.

Determine the acceleration or increase in speed acquired during each period of time.

Compute the ratio of the speed at the end of each period to the time. What simple relation seems to exist between

this ratio and the acceleration? Express as a formula for speed or velocity.

Compute the ratio of the total distance at the end of each period of time to the square of the time. Obtain the average acceleration and the average ratio. What simple relation seems to exist between the acceleration and the ratio of the distance to the square of the time? Express as a formula. Transpose and obtain a formula for distance in terms of acceleration and time.



TABULATION

NUMBER OF THE PERIOD (TIME)	I	II	III	IV	V
Total distance at end of period	....	....	....	....	....
Distance rolled each period	....	....	....	....	....
Speed at end of each period	....	....	....	....	....
Acceleration in each period	....	....	....	....	....
Ratio (speed ÷ time)	....	....	....	....	....
Ratio (distance ÷ square of time)	....	....	....	....	....
Average acceleration					....
Average of ratios (distance ÷ sq. of time)					....

OPTIONAL

Compute by means of formulas the speed at the end of the tenth period and the total distance the ball would have rolled at the end of the tenth period.

Fasten one end of a wax thread to the iron ball and suspend it in such a way that you have a pendulum exactly 36 centimeters long, measuring from the center of the ball to the point of suspension. This can best be done by determining the radius of the ball with the caliper and obtaining the required distance from the top of the ball to the point of suspension.

If a regular pendulum suspension clamp is used, the cord should be placed between the clamp bar and the small side plate at the center binding post. Turn the milled head screw tight and the cord is firmly held.

Set the pendulum swinging through an arc of ten centimeters and count the number of single vibrations in one and a half minutes. To do this one student should keep record of the time while the others count the vibrations. The timekeeper holds the pendulum five centimeters to one side of the position of rest and releases it at some particular second. The students counting should be warned one second or more before the close of the period.

Repeat using a pendulum of 81 centimeters in length. Use the same ball and the same arc.

For a third test use the 81-centimeter pendulum with double the arc and determine the number of vibrations in the same length of time.

For a fourth test use a wood ball in place of the iron ball. Use a length of 81 centimeters and an arc of ten centimeters.

Compute the period or time of one vibration for each pendulum.

Tabulation

Material	Length	Arc	Time	No. of Vib.	Period
Iron	36 cm.	10 cm.	90 sec.	....	....
Iron	81 cm.	10 cm.	90 sec.	....	....
Iron	81 cm.	20 cm.	90 sec.	....	....
Wood	81 cm.	10 cm.	90 sec.	....	....

I. State the effect of material and length of arc on the time of one vibration.

II. State the exact variation discovered between the lengths and the periods of the different pendulums.

III. State the exact variation discovered between the lengths and the number of vibrations of the pendulums.

Optional

By means of the relation between the length and the period discovered in the experiment, compute the length of a pendulum that would vibrate once a second.

In this experiment all students at a table are to work in a group: one student keeping record of the time and the others counting the number of vibrations.

Suspend a pendulum from a hook in the ceiling over a point near one end of the table. To measure the length of the pendulum, slip the ring on the end of the steel tape measure over the hook in the ceiling and measure distance to the top of the iron mass or bob. To this distance add one-half of the vertical diameter or length of the iron mass. Notice that the small units on the measuring tape are tenths and hundredths of the foot.

Draw a short chalk line on the table directly under the center of the bob and parallel to the side of the table. Set the pendulum swinging through an arc of about 20 inches at right angles to the chalk line and parallel to the end of the table.

The timekeeper should take a position at the end of the table and, when ready to begin the test, start the stop watch at the exact instant that the pendulum passes over the chalk line in its movement from the timekeeper's right to left. After the pendulum has vibrated for about ten minutes, give a warning signal and stop the stop watch as the bob passes over the chalk line going in the same direction (right to left). Record the time or duration of the test.

The students counting should record a mark at each passage of the pendulum over the chalk line from the same direction (complete vibrations). Determine the number of single vibrations between the starting and stopping of the watch.

Compute the period or time of a single vibration to the third decimal place. Substitute the square of the period obtained, the length of the pendulum, and the square of 3.1416 in the pendulum formula and compute the acceleration of a falling object at your latitude and elevation.

Tabulation

Distance from hook to bob	..... ft.
Diameter or thickness of bob	..... ft.
Length of pendulum	..... ft.
Duration of test	..... seconds
Number of complete vibrations	.....
Number of single vibrations	.....
Time of a single vibration	..... seconds
Square of 3.1416	.....
Acceleration of gravity	.....

Optional

With the acceleration obtained, compute, by means of the pendulum formula, the length in inches of a pendulum that will vibrate once a second.

The force of gravity acting on an object on an inclined plane is resolved into two forces. One of these component forces is the force causing the object to roll down the incline. The magnitude of this force can be determined by the principle of the parallelogram of forces.

In the diagram the line *RW* represents the force of gravity or weight and the line *FR* represents the force producing acceleration or motion down the incline. The triangles *ABC* and *WRF* are similar. Hence the force producing acceleration has the same relation to the weight of the object as the height of the plane has to its length.

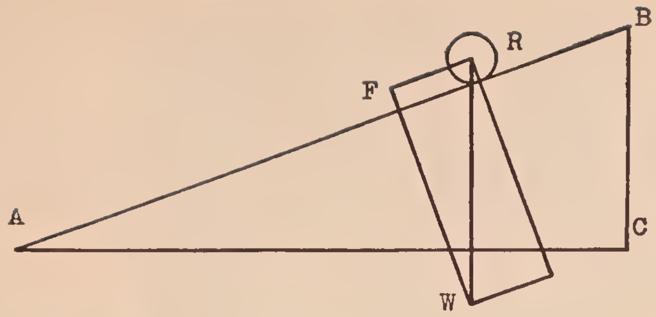
Weigh the ball to the nearest tenth of a gram. By means of blocks raise one end of the acceleration apparatus, or grooved plank, 20 centimeters above the table. Record the length and the height of the incline. Compute the magnitude of the force causing the ball to roll down the incline.

Wipe the groove with a damp cloth and rub it thoroughly dry. Sift on the groove a thin and uniform layer of lycopodium powder. Carefully release the ball at the edge of the groove just above the guide. Blow away the powder so that the track of the rolling ball will be seen by the powder which remains.

Place the meter stick with its metric edge down the center of the groove and measure in centimeters the distance the ball rolled down the plank during the first four oscillations to the side or the first four equal periods of time. From these results determine the increase in distance passed over in each period of time and record the average as the acceleration.

Raise the end of the plank 35 centimeters above the table. Record the length and height of the incline and compute the force producing acceleration. Determine as before the acceleration produced in the rolling ball by the new force.

Express the relation or ratio of the two accelerations produced. Also the ratio of the two forces producing acceleration. Record the ratios in decimal form to the second place. State the relation of the ratios discovered in the form of a law.



Tabulation

Test Number	I	II
Weight of ball	....	....
Height of incline	....	....
Length of incline	....	....
Force producing acceleration	....	....
Distance — First period	....	....
Distance — Second period	....	....
Distance — Third period	....	....
Distance — Fourth period	....	....
Acceleration (average)	....	....
Ratio of accelerations	....	
Ratio of accelerating forces	....	

Optional

If the force producing acceleration was the weight of the object, or if the angle of the incline was 90 degrees and the object fell, compute from your results its acceleration or the acceleration of a falling object. With a stop watch determine the period or time of one oscillation of the ball. Change the acceleration obtained (centimeters per "period," per "period") to centimeter per second, per second. If your result is not the true acceleration of a falling object, explain the cause of the error.

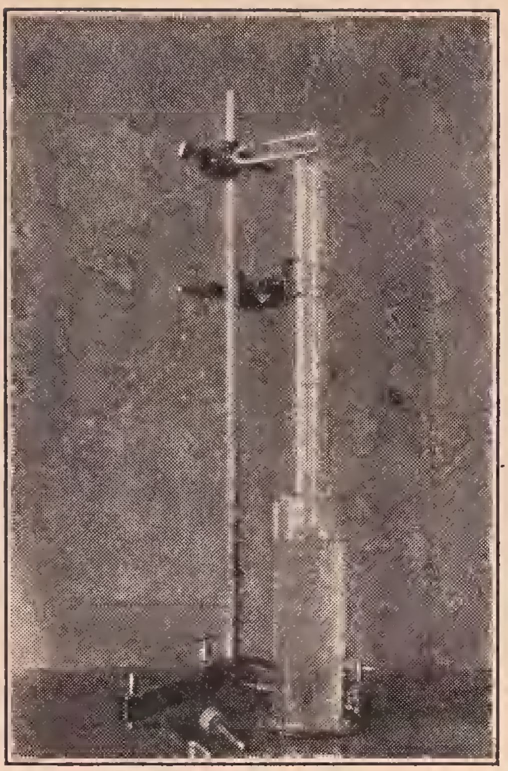
Push a pencil into the rubber stopper and use as a tuning-fork hammer. Nearly fill the jar with water and clamp the tube in a vertical position so that its lower end will be near the water surface.

If two students work together, one should set the fork in vibration and hold it as near as possible, without striking, to the upper end of the tube. The other should raise the jar of water, and note the level of water in the tube when the greatest reinforcement of the sound is produced. Place the rubber band on the tube at this level. Make several trials, readjusting the band if necessary, until sure that it is properly placed.

Measure the distance from the rubber band to the end of the tube. Change the position of the band and exchange work. Record the average of your results as the length of the air column.

Experiment has shown that the length of a resonating air column is affected by the diameter of the tube. The correction is made by adding .4 of the diameter to the length.

Compute the wave length of the sound produced by the fork. From the frequency, indicated on the fork, and the wave length, calculate the speed of the sound. This would be the speed at the temperature of the air in the tube or the temperature of the water. Determine this temperature and compute the speed of sound at zero degrees Centigrade.



Tabulation

Frequency of Fork	......	
Length of air column	......	in.
Diameter of air column	......	in.
Corrected air column	......	in.
Wave length	......	ft.
Calculated speed of sound	......	ft./sec.
Temperature in tube	......	degrees
Temperature correction	......	ft.
Computed speed at zero C.	......	ft./sec.
Correct speed at zero C.	......	ft./sec.

Optional

Find by experiment the wave length of the sound produced by a fork of unknown frequency. Compute the correct speed of sound at the room temperature, and determine the frequency of the fork.

Experiment 29 — WAVE LENGTH BY INTERFERENCE

Connect a funnel to the main branch of a Y-tube with a short piece of heavy-wall rubber tubing. On a second Y-tube place a heavy-wall tube about 30 inches long. Place the Y-tubes, where the rubber overlaps, in universal clamps on two vertical support rods. Connect the upper prongs of the Y-tubes with a tube 12 inches long and the lower prongs with a tube 25 inches long. See that the tubes are resting loosely in the clamps.

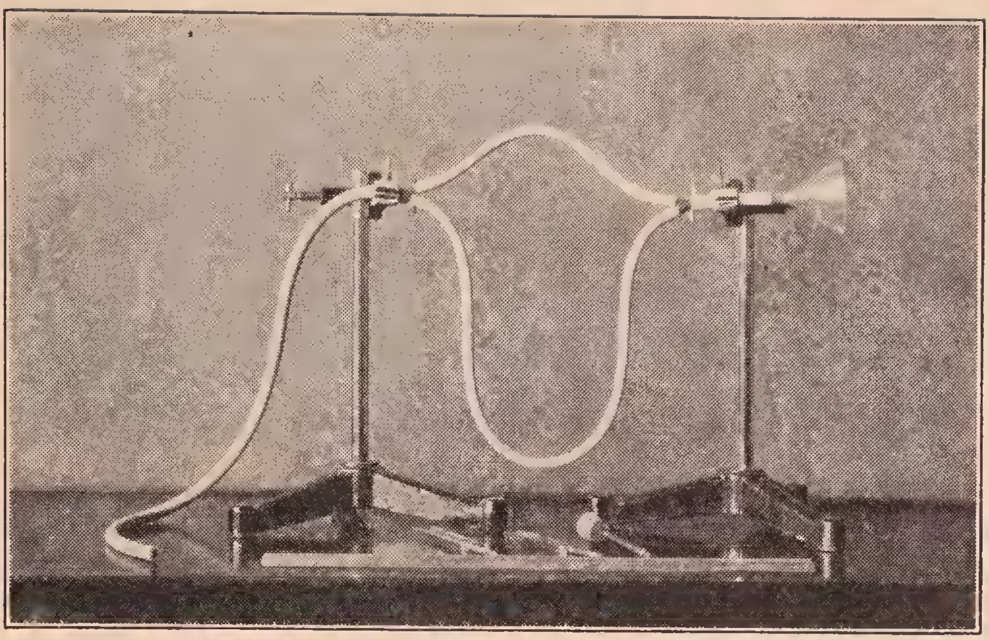
It is evident that sound waves entering the funnel will divide at the first Y-tube and unite at the second. If one branch is one-half a wave length longer than the other branch, the condensation of one wave and the rarefaction of the other wave will reach the single tube at the same time and little or no sound will be heard.

One student should hold the end of the tube at his ear. For sanitary reasons, the end of the tube should be held in the closed hand with the finger and thumb pressing against the ear. A second student should hold the vibrating fork (512 vibrations) before the funnel. The fork should be set into vibration by plucking. While the fork is vibrating, close the longer branch by pinching the tube and note the change in the loudness of the sound.

Replace the longer branch with a tube 29.5 inches long and repeat the test. For the final test use the tube for the longer branch that best produces the least sound when both tubes are open, or the greatest contrast when one tube is closed and opened. Make final adjustments by sliding the tubings farther on or off of the forks of the Y-tubes.

Measure carefully the length of each branch and determine the wave length of the sound produced by the fork. Make a second trial using a fork of 384 vibrations.

Determine the temperature of the room and compute the velocity of sound at room temperature. From the formula expressing the relation between velocity, frequency, and wave length, compute the wave length of the sound produced by each fork.



Tabulation

Frequency of Fork	512	384
Length of long branch	....	....
Length of short branch	....	....
Wave length by experiment	....	....
Temperature of room	....	....
Velocity of sound at room temperature	....	....
Wave length by formula	....	....

Optional

Disconnect the branches from the system and connect the heavy-wall tube directly to the funnel. While one student is listening at the end of the tube, the other should hold the vibrating fork (384 vibrations) in a vertical position near the funnel and slowly turn it on its axis one-fourth of a revolution. Describe and explain the result.

Experiment 30 — LAWS OF VIBRATING STRINGS

Law of Length

Cut a piece of steel piano wire No. 24 about 100 centimeters long. Fasten one end of wire firmly to an iron ring and the other end to a small washer. Place the iron ring on a table clamp fastened to the edge of table and the washer on the hook of a 30-lb. capacity spring balance also clamped to the table.

Place two triangular blocks or bridges under the wire and move the spring balance until the wire is under a tension of nine kilograms.

Place the bridges at such a distance apart that the wire will be in unison with a C (256 vibrations) tuning fork. Set the tuning fork in vibration with a hammer made by placing a rubber stopper on the end of a lead pencil. See that the tension is correct before recording the length or distance between the bridges.

If you are not musically inclined, the string may be tuned by finding a point at which few or no beats are produced when both string and fork are vibrating.

With the same tension determine, by moving the bridges, the length of wire that will produce G (384 vibrations). Compute the ratio of the frequencies and the inverse ratio of the lengths. Compute ratios to the second decimal.

Law of Tension

With the same length of wire as obtained with the G tuning fork, vary the tension until the wire produces C (256 vibrations). Compute the ratio of the frequencies and the ratio of the square roots of the tensions.

State each law proved in the experiment.

Tabulation

Law of Length

No. of Wire	Frequency	Tension	Length
24	256	9 kg.	....
24	384	9 kg.	....

Ratio of frequencies ....
Ratio of lengths (inverse) ....

Law of Tension

No. of Wire	Frequency	Tension	Length
24	384	9 kg.	....
24	256	....	....

Ratio of frequencies ....
Ratio of square roots of tensions ....

Optional

Use steel piano wire No. 26 and a tension of nine kilograms. Move the bridges and determine the length of wire that will produce C (256 vibrations). With the law of length compute what the frequency of the No. 26 wire would be if the length remained the same as that of the No. 24 wire when its tension was nine kilograms and its frequency 256.

Compute the ratio of the frequencies of the two wires if their lengths were the same. With a micrometer screw measure the diameter of each wire. Compute inverse ratio of diameters.

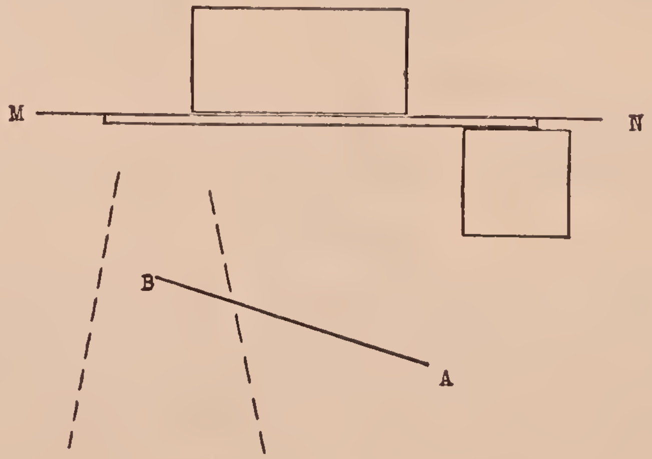
No. of Wire	Frequency	Tension	Length	Diameter
24	256	9 kg.	....	....
26	256	9 kg.	....	....
26	...	9 kg.	....	....

Ratio of frequencies (lengths constant) ....
Ratio of diameters (inverse) ....

Draw a line MN across the center of a right-hand page of your notebook. Place the mirror in a vertical position with the edge of its silvered surface exactly above the line MN. The mirror may be held in position by means of two blocks.

In front of the mirror draw a line AB about three inches long, with the end A about three inches and the end B about two inches from the line MN.

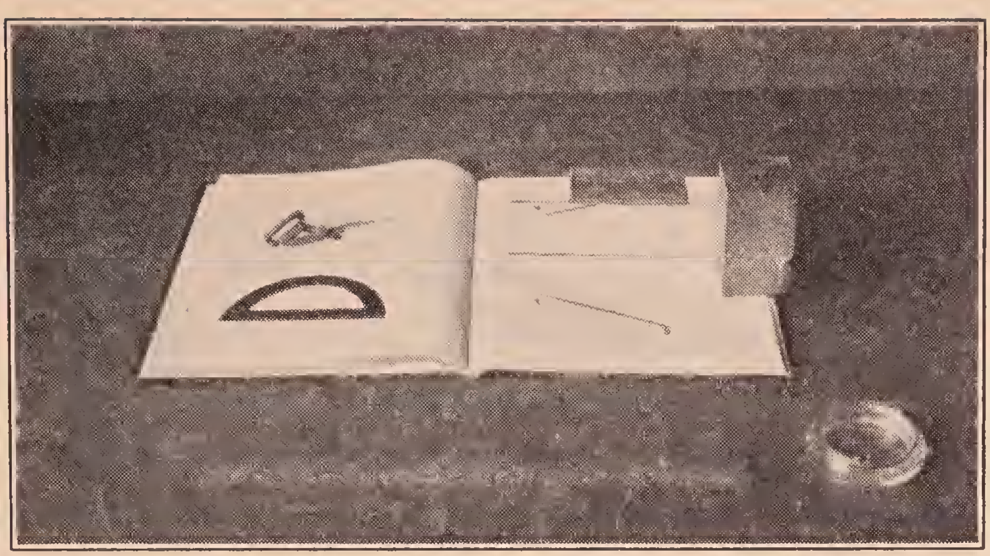
Set a pin in the point A and draw two lines along which its image can be seen. This can best be done by placing a ruler on the page and, sighting along one edge, point it in such a direction that a line drawn along its edge, if extended back of the mirror, would pass through the image of the pin. Since the image can be seen in each of these lines, it must be at their intersection. Better results will be obtained the farther apart these two lines are taken.



Place the pin at B and in a similar manner draw two sight lines toward its image.

Remove the mirror and extend the first two lines until they meet at a point C. Mark the point of intersection of the second pair of lines D. Draw the line CD. Also the lines AC and BD.

Measure the distance of each point, A, B, C, and D, from the mirror or the line MN.



Tabulation

Length of line AB	....
Length of line CD	....
Distance of A from mirror	....
Distance of C from mirror	....
Distance of B from mirror	....
Distance of D from mirror	....

What does the line CD represent and how does it compare in length with AB?

From these results what may be stated concerning the size and location of an image in a plane mirror?

Optional

Draw a line MN near one edge of a page of your notebook. Place the mirror on the line as before. Set a pin about three inches from the line MN and near one side of the page.

Near the other side of the page draw a line AB along which the image of the pin can be seen, using ruler as before. Remove the mirror and extend the line AB to the line MN. Draw a line from the pin point P to the point I where AB and MN intersect.

What do the lines AI and PI now represent? Erect a perpendicular DI to the line MN at the point I. By means of a protractor measure the angles AID and PID. What do these angles represent and what law has been proved?

Experiment 32 — CONVEX CYLINDRICAL MIRROR

Part I — Focal Length

Place the mirror in a vertical position near the center of the right-hand page of your notebook and with a sharp pencil draw a line along the base of the concave surface.

Remove the mirror and determine by construction the mid-point of the curve. Mark it V (vertex). From V draw chords to each end of the curve.

At the mid-point of each of these chords construct a perpendicular and extend them until they meet at a point C (center of curvature).

Measure and record on your drawing the radius of curvature and the focal length of the mirror.

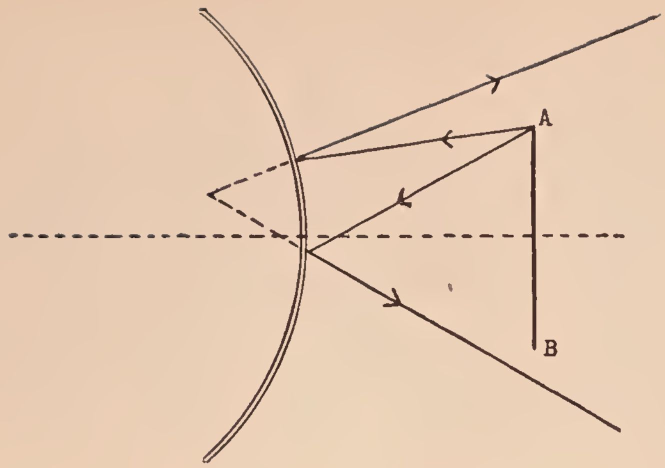
Part II — Images

Place the mirror near the center of a second page and draw a line along the base of the convex side. Remove the mirror and draw the principal axis in dotted line.

At a distance of one and a half times the focal length in front of the convex side of the mirror, draw a line *AB* four centimeters long at right angles to the axis. Place a pin at *A* and replace the mirror.

By means of a ruler draw two lines (one on each side of the pin) that if extended would appear to pass through the image of the pin. Stand the pin at *B* and draw, as before, two lines toward its image.

Remove the mirror and extend each set of lines until they intersect at points *a* and *b*. Draw the line *ab*, the image of the line *AB*. Connect *A* with the points where the sight lines strike the mirror. Show by arrows the direction of the rays of light as they leave *A* and after reflection. Connect *B* in a like manner. Describe the image as to size (larger or smaller than the object); form (erect or inverted); kind (real or virtual).



TABULATION

Radius of curvature	....
Focal length of mirror	....
Size of image	....
Form of image	....
Kind of image	....

OPTIONAL

In the second diagram measure the length of the image and its distance from the mirror. Compute the ratio of the size of the image to the size of the object. Also the ratio of the image distance to the object distance. Each ratio to be expressed to the second decimal place.

Size of image (ab)	....
Size of object (AB)	....
Distance of image to mirror	....
Distance of object to mirror	....
Ratio of sizes	....
Ratio of distances	....

Place the mirror in a vertical position near the center of the right-hand page of your notebook. With a sharp pencil draw a line along the base of the concave surface.

Remove the mirror and draw the chord connecting the two ends of the curve. At the mid-point of the chord draw a perpendicular or principal axis. Chord and axis to be in dotted lines.

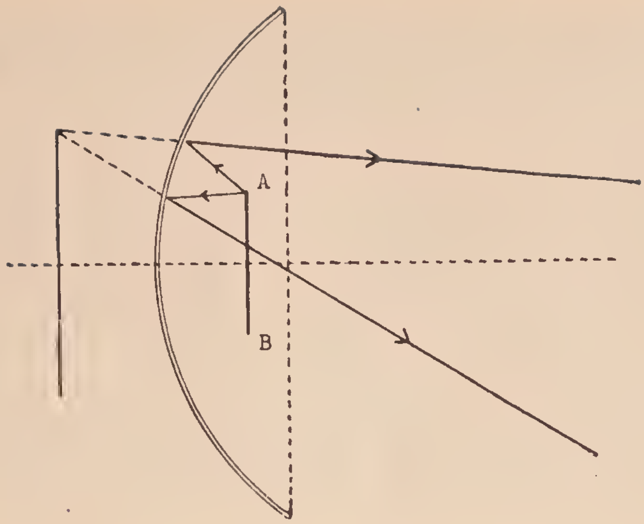
Obtain the focal length and radius of curvature from the previous experiment and indicate on your drawing the location of the vertex (V), the principal focus (F), and the center of curvature (C).

At a point midway between V and F draw a perpendicular *AB*, extending one centimeter each side of the axis. Place a pin at *A* and replace the mirror. Sighting along the edge of a ruler, draw two lines that if extended would appear to pass through the image of *A*. The sight lines are more easily drawn if, after the image is found, the eye is held stationary and the ruler then moved to the correct position.

Remove the mirror and pin and extend the sight lines to the mirror and to the point of intersection. Lines back of the mirror are to be dotted. Connect *A* with the points where the sight lines strike the mirror. Show by arrows the direction of the rays of light as they leave *A* and after reflection.

Assuming the image of *B* to be similarly placed in respect to the axis, draw the line *ab* as the image of the object *AB*. Record in the tabulation the position, size, form and kind of the image.

Place the mirror in the center of another page and make a second diagram with the object (*AB*) placed midway between F and C. Describe the image. If an image or object is in front of the mirror, its location is given in relation to the points V, F and C.



Tabulation

Location of Object	Between V and F	Between F and C
Location of image	....	....
Size of image	....	....
Form of image	....	....
Kind of image	....	....

Optional

In the second diagram measure the length of the image and its distance from the mirror. Compute the ratio of the size of the image to the size of the object. Also the ratio of the image distance to the object distance. Each ratio to be expressed to the second decimal place.

Size of image (ab)	....
Size of object (AB)	....
Distance of image from mirror	....
Distance of object from mirror	....
Ratio of sizes	....
Ratio of distances	....

Experiment 34 — SPHERICAL MIRRORS

Part I — Focal Length

Clamp the flame and concave mirror on the optical bench 80 centimeters apart. Support the screen between the flame and mirror a little to one side of the line connecting their centers. Move the screen back and forth until a distinct image is obtained.

Measure and record as (A) the distance between the flame (object) and the center of the mirror. Record as (B) the distance between the screen (image) and the mirror. Compute the focal length F from the mirror formula.

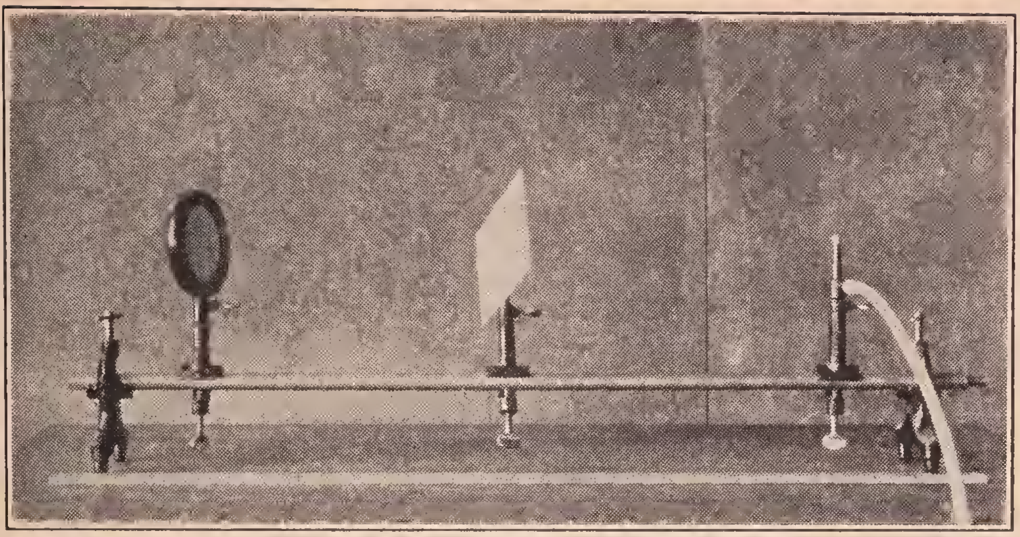
Part II — Images

From the results of Part I, calculate the radius of curvature of the mirror, which is twice the focal length. Place the flame at this distance from the mirror. It will then be at the center of curvature C. Obtain the image of the flame by holding the screen near the side of the flame. Move the screen until the image is very sharp or distinct.

It is customary to call the flame the object. Is the image as now seen larger or smaller than the object? Is it erect or inverted? Where is it with reference to the center of curvature C, principal focus F, and vertex V? Is it real or virtual? Record the answers to those questions in the table below under the headings of "Size," "Form," "Location," and "Kind," respectively.

Place the object at the different locations indicated in the tabulation. Find the image in each case and describe it as above.

Change the mirror about and use the convex surface. Place the flame near the mirror and describe the image. Repeat with the flame a meter from the mirror.



Tabulation

Part I

Distance from object to mirror (A)	....
Distance from image to mirror (B)	....
Focal length of concave mirror (F)	....

Part II

Description of Image	Location	Size	Form	Kind
Object at C, concave mirror	....	....	....	....
Object beyond C	....	....	....	....
Object between C and F	....	....	....	....
Object between F and V	....	....	....	....
Object near convex mirror	....	....	....	....
Object a meter from mirror	....	....	....	....

Optional

An object is placed 15 centimeters from a concave mirror whose radius of curvature is 12 centimeters. How far from the mirror is the image? Solve by formula and by construction.

Experiment 35 — INDEX OF REFRACTION OF WATER

Fill a six-inch battery jar with water until the surface is about one inch from the top of the jar.

Place nails in the two holes of the index of refraction board. The head of the nails should be on the back of the board or on the side opposite the groove.

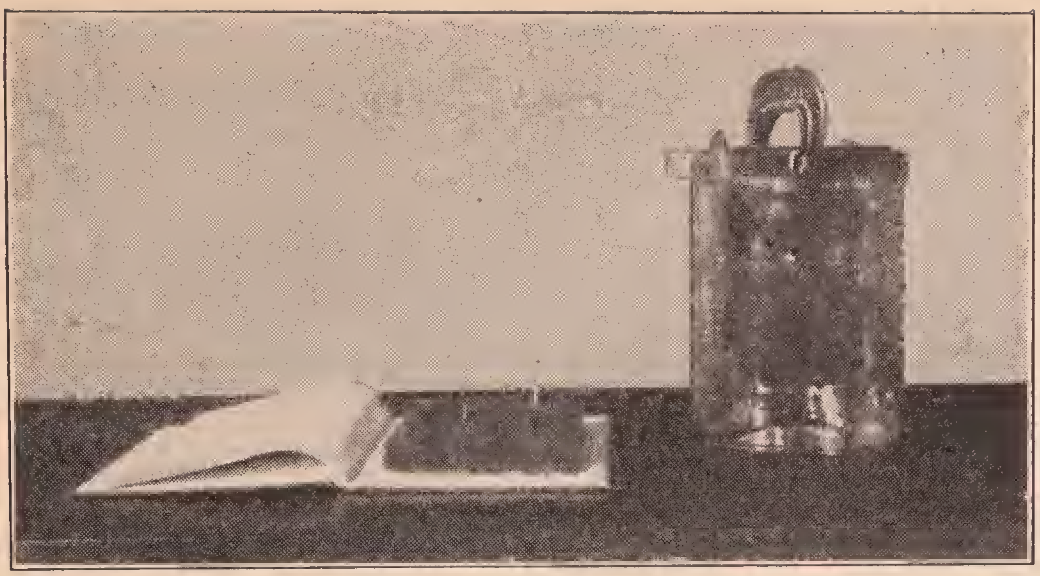
Place a smaller block across the top of the jar and clamp it to the back of the refraction board in such a manner that the board will be in a vertical position with the upper edge of its groove just at the surface of the water at all points.

Place a third nail on the upper edge of the board parallel with the other two nails. Looking down into the water, carefully place the nail on the edge in such a position that the three nail points will apparently be in the same straight line. Measure the distance from the center of the nail on the edge to the corner of the board.

Remove the board from the water and take out the nails. Wipe the board and nails thoroughly dry. Draw a line MN across the center of the page of your notebook to represent the surface of the water. Place the board on the page with the upper edge of the groove on the line MN. Locate on the page the position of the nail in the air (A). By placing the point of the nail in the hole, mark the position of the nail near the surface of the water (S) and in the water (W).

Remove the board and draw the incident ray from W through A to the point of incidence in the surface line MN. Connect the point of incidence to A as the refracted ray. Construct a normal to MN at the point of incidence. From a point on each of the rays equidistant from the point of incidence, construct a perpendicular to the normal. Measure the two perpendiculars and record as IN and RN.

Compute the sine of the angle of incidence and the sine of the angle of refraction. Compute the index of refraction of light passing from water into air by the ratio of the perpendiculars and by the ratio of the sines.



Tabulation

Length of perpendicular (IN)	....
Length of perpendicular (RN)	....
Index of refraction ($IN \div RN$)	....
Hypotenuse of right triangles	....
Sine of angle of incidence	....
Sine of angle of refraction	....
Index of refraction (Ratio of Sines)	....

Optional

By means of a protractor measure the angle of incidence and the angle of refraction. From the Table of Sines given in the Appendix obtain the sine of each angle and compute the index of refraction of light passing from water into air.

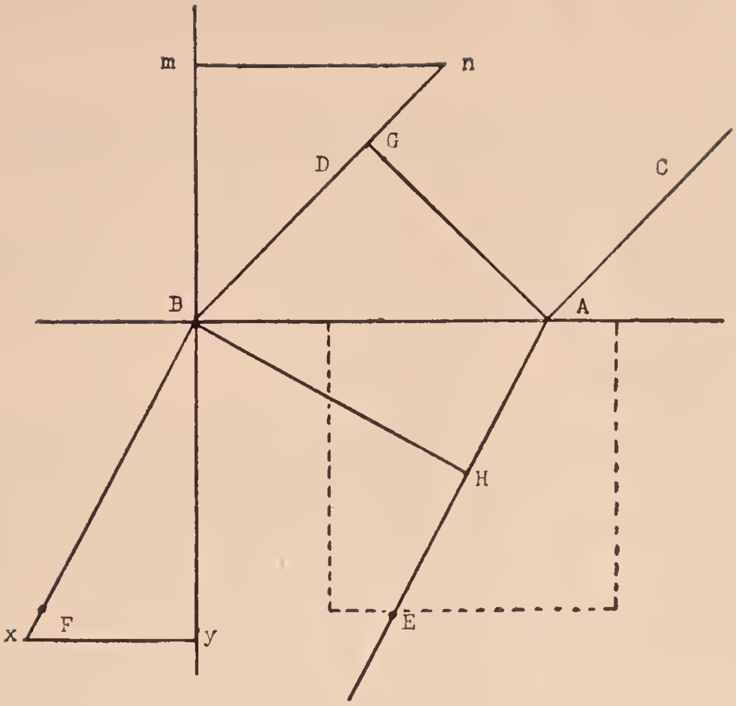
Angle of incidence (degrees)	....
Angle of refraction (degrees)	....
Sine of angle of incidence	....
Sine of angle of refraction	....
Index of refraction	....

Draw a line across the center of the right-hand page of your notebook. On this line place a point A, 3 centimeters from the end, and a point B, 10 centimeters from A. At the points A and B draw the lines AC and BD respectively, making angles of 45 degrees with the line AB.

Place the block of glass in the position shown by dotted lines in the diagram. The ground edge of the block should be on the line AB. Place two pins in line AC about 3 centimeters apart, and looking *through* the glass from edge to edge, place a third pin at such a point E, on the lower edge of the block, that all three pins will appear to be in the same straight line. Slide the block along on the line AB and in a like manner determine the point F.

Remove the glass and draw the lines AE and BF. Draw AG perpendicular to BD and BH perpendicular to AE. Erect a perpendicular (normal) to the line AB at the point B. Extend the lines BD and BF to a distance of 10 centimeters from B and at the extremity of each draw a perpendicular to the normal. Measure and record the various lines indicated in the tabulation.

What do the lines AG and BH represent? What do the lines BG and AH represent? What does the ratio of MN to XY measure? What is proved by the comparison of the two ratios in the tabulation?



Tabulation

Length of line *BG*	....
Length of line *AH*	....
Ratio of *BG* to *AH*	....
Length of perpendicular *MN*	....
Length of perpendicular *XY*	....
Ratio of *MN* to *XY*	....
Speed of light in air	300,000,000 m./sec.
Speed of light in glass	....

Optional

Prove geometrically from your drawing that the two ratios in the tabulation are equal.

Draw a line MN across a page of your notebook. Place the prism on end so that one side of its base will lie along the central portion of the line MN. With a sharp pencil trace the perimeter of the base of the prism. Place the prism on the other side of the line as in the diagram and again draw the perimeter.

At a point B near the center of the side of the base of the prism, draw a line which will make an angle of 42 degrees with the base. Extend this line to the line MN at the point A. Connect A with a point C and make an angle of 42 degrees with the other base.

Place two pins on the line AB and replace the prism on the upper perimeter. Look through the prism from the opposite side, and by means of a ruler draw a line that if extended would appear to pass through the two pins or along the line AB. In a similar manner draw a line that coincides with the images of two pins in the line AC.

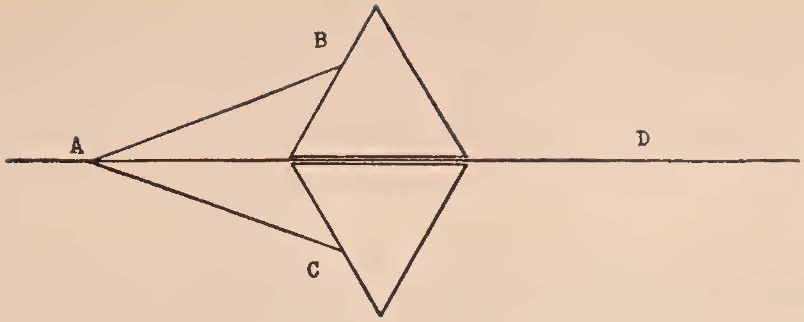
Remove the prism and extend the lines just drawn to the perimeter in one direction and until they intersect in the other direction. Draw the path of the light as it passes through the prism. Draw a normal where it enters the glass and also where it leaves the glass. Measure the angles indicated in the tabulation. Letter all angles on drawing and in the tabulation.

I. What do the lines AB and AC represent?

II. What do the lines constructed on the opposite side of the prism represent?

III. What does the intersection of the lines in II represent?

IV. In what direction is the ray of light bent as it enters and as it leaves?



Tabulation

Angle of incidence ( )	.... degrees
Angle of refraction of prism ( )	.... degrees
Sum of angles (incid. and refract.)	.... degrees
Angle of deviation ( )	.... degrees
Refracting angle of prism ( )	.... degrees
Sum of angles (deviat. and prism)	.... degrees

Optional

Obtain from a Table of Sines given in the Appendix of Manual, the sine of one-half of the sum of the angle of deviation and the refracting angle of prism. Also the sine of one-half of the refracting angle of prism. Divide the first sine by the second and state what the quotient represents.

Experiment 38 — LENSES — FOCAL LENGTH AND IMAGES

Part I — Focal Length

Place a right-angled support on one end of the optical bench and in it clamp the gas burner so that the plane of the flame will be at right angles to the bench. Support the metal screen near the other end of the bench. Between the screen and flame support a lens holder containing the double convex lens of two-inch diameter. The centers of the flame, lens, and screen should be at the same height. Turn up the flame until it is quite high.

Find by trial a position for the lens between screen and flame that will give a distinct image of the flame on the screen. Great care should be taken in moving the lens lest it fall from its holder and strike the bench. If the screw of the right-angled support is well loosened, the support will slide freely on the bench. Measure the distance from the lens to the flame and record as the object distance (A). Record the distance from lens to the screen as the image distance (B). Substitute in the lens formula and compute the focal length.

Part II — Images

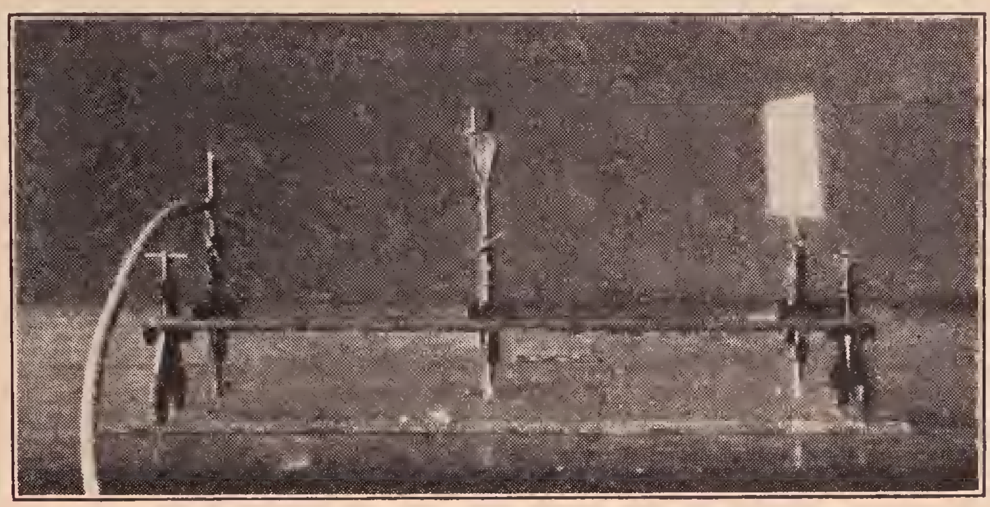
Place the gas flame and screen on opposite sides of the lens and each twice the focal distance from the lens. The flame and screen are now at points called secondary foci. Describe the image as to size, form, location, and kind. For Part II, turn off the gas until the flame is low.

Place the flame between the principal focus (P.F.) and secondary focus (S.F.) of the lens. Move the screen until a sharp focus or image is obtained. Describe the image.

Place the flame beyond the secondary focus or more than twice the focal distance from the lens. Find the image and describe it as above.

Place the flame between the principal focus and lens. Can an image be obtained on the screen? Look through the lens at the flame and describe the image seen.

Replace the double convex lens by the double concave lens and describe the image obtained when the flame (object) is near the lens and also when the flame is at some distance (60 cm.) from the lens.



Tabulation

Part I

Distance from object to lens	(A)	....
Distance from image to lens	(B)	....
Focal length of convex lens	(F)	....

Part II

Description of Image	Location	Size	Form	Kind
Object at S.F. convex lens	....	....	...	....
Object between P.F. and S.F.	....	....	....	....
Object beyond S.F.	....	....	....	....
Object between P.F. and lens	....	....	....	....
Object near concave lens	....	....	....	....
Object 60 cm. from lens	....	....	....	....

Optional

A three-inch slide is to be projected on a screen 20 feet away from the lantern, so that the picture will be 8 feet long. Find the focal length of the lens required.

Experiment 39 — COEFFICIENT OF LINEAR EXPANSION

Fill the boiler about one-half full of water and light the gas. Regulate the gas so that the flame does not come up the side of the boiler.

Measure to the nearest millimeter the length of the metal rod which is held in the center of the steam jacket.

Before replacing the jacket on the stand determine the method of reading the micrometer screw. (Determine how far the screw moves lengthwise when it is turned through one division on the disc or circular scale.)

Replace the jacket on the stand and turn the micrometer screw until it just touches the end of the metal rod. This point of contact can be accurately determined within one division of the circular scale by the sense of touch, if the end of the rod is moved slightly up and down as the screw is moved slowly toward the rod.

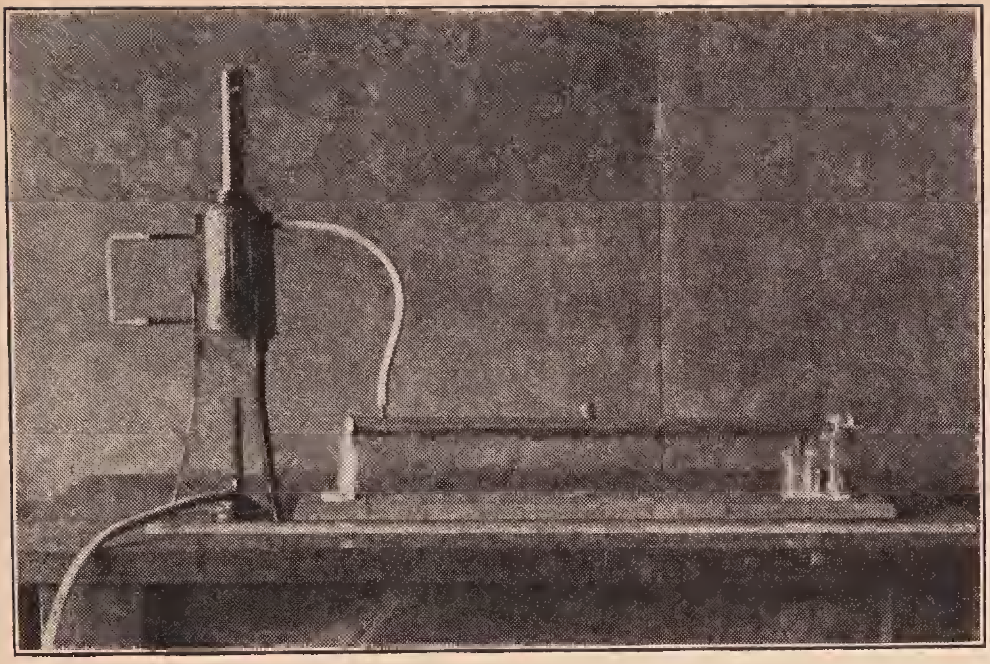
Read the linear and circular scales. If the linear scale is not numbered, consider the line nearest the end of the jacket as the zero line.

Turn the screw back three or four millimeters to allow for expansion. Connect the jacket to the boiler and pass steam through for five or six minutes.

Determine the temperature of the room which may be considered as the temperature of the rod before expansion. The final temperature of the rod will be that of the steam, 100 degrees C.

While the steam is still passing, take the second micrometer reading as before. Place a cloth between the hand and the jacket, as it is too hot to touch.

From the original length, change in temperature, and expansion, compute the coefficient of linear expansion of the rod.



Tabulation

Length of rod	.... mm.
Micrometer reading	.... mm.
First temperature	.... deg. C.
Second temperature	.... deg. C.
Micrometer reading	.... mm.
Expansion of rod	.... mm.
Coefficient of expansion	....

Optional

The steel rail of a railroad track is 33 feet long. If the coldest temperature is 30 degrees below zero, F., and the warmest 120 above, what space should be left between rails if laid when the temperature is 72 degrees, F.?

Fill the boiler about two-thirds full of water and place on the tripod. Regulate the gas so that none of the flame comes up the side of the vessel. (A 600-cc. glass beaker may be used for the boiler.)

Place a thread through the ball and make a loop of such length that, when suspended from a small stick placed across the top of the boiler, the ball will be entirely immersed in the water. Weigh the ball and thread to the nearest tenth of a gram and suspend it in the boiling water.

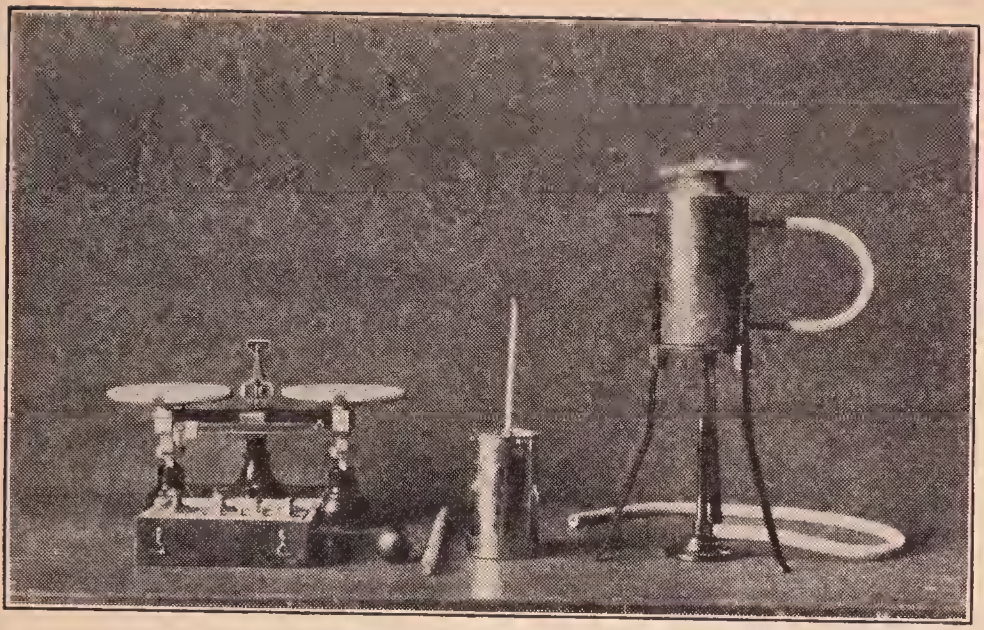
Weigh the dry calorimeter. Fill the calorimeter about three-fourths full of water at a temperature a little (3 or 4 degrees) below that of the room. Weigh the calorimeter and contents.

Take the temperature of the water, estimating tenths of a degree, and immediately transfer the ball to the calorimeter. Be careful to transfer as quickly and with as little water as possible. By means of the thread move the ball up and down in the water and watch the thermometer.

Record the highest temperature that can be obtained. This is the resulting or final temperature of the ball and water.

The temperature of the boiling water and first temperature of the ball may be taken as 100 degrees Centigrade.

Compute the number of calories given off by the ball and the number absorbed by the water. By the method of mixtures compute the specific heat of the ball.



Tabulation

Material tested	....
Weight of the ball	....
Weight of the calorimeter	....
Weight of the calorimeter and water	....
Weight of the water taken	....
Temp. of boiling water or ball	....
Temp. of calorimeter and water	....
Resulting temperature	....
Fall of temperature of ball	....
Rise of temperature of water	....
Specific heat obtained	....
Correct specific heat	....

Optional

The vessel will change temperature the same as the water it contains. If the specific heat of the vessel is 0.1, compute the heat absorbed by the vessel. Taking this into consideration, compute again for a more accurate specific heat of the ball.

Experiment 41 — TEMPERATURE OF GAS FLAME

Cut from the spool of chromel wire No. 28 a piece about a foot long. Fasten one end to an iron ball by putting it through the hole and then twisting the end several times around the wire above the ball. In the other end of the wire twist a loop large enough to go over the head of a spike. The ball should hang about eight inches below the nail.

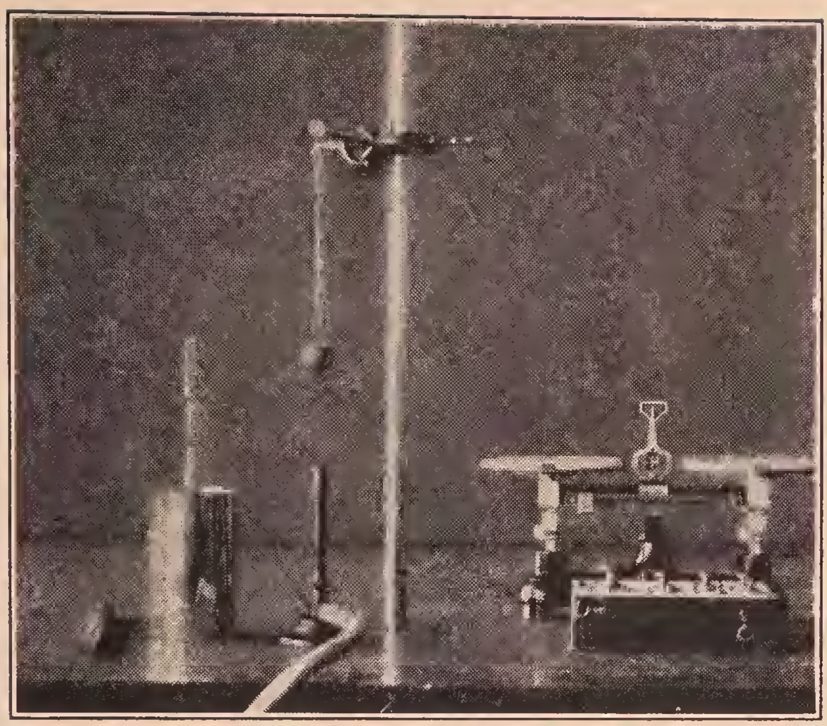
Weigh the ball and wire on a platform balance to the nearest tenth of a gram. Place the nail in a clamp on the vertical support rod and suspend the ball so that it will be entirely surrounded by the upper part of a Bunsen burner flame.

Weigh the calorimeter. Fill it about three-fourths full of cold water and weigh again. The temperature of the cold water should be about five or six degrees below room temperature.

When the ball has been in the flame three or four minutes after becoming red-hot, take the temperature of the cold water. Move the flame to one side and quickly submerge the ball in the water by bringing the vessel up from underneath the ball.

Put in a thermometer and keep the water in motion by stirring with the thermometer and by raising and lowering the vessel. Record the highest temperature obtained.

Compute the heat received by the water and by the vessel. (Consider the specific heat of the vessel to be 0.1). With x as the change of temperature of the ball, express the number of calories given off by the ball. Equate the calories given off and the calories received and compute the fall of temperature of the ball. Determine the temperature of the flame.



TABULATION

Weight of calorimeter	....
Weight of calorimeter and water	....
Weight of water	....
Temperature of cold water	....
Resulting temperature	....
Calories received by water	....
Calories received by vessel	....
Calories given off by ball	....
Fall of temperature of ball	....
Temperature of flame (Centigrade)	....

OPTIONAL

A 2-pound iron ball is heated for some time in a furnace and then dropped into 6.8 pounds of water at 40 degrees F. The resulting temperature of the water is 100 degrees. Compute the temperature of the furnace on the Fahrenheit scale.

Experiment 42 — LATENT HEAT OF SNOW

Weigh the dry calorimeter to the nearest tenth of a gram.

Fill the calorimeter about one-half full of water ten or twelve degrees Centigrade above room temperature and weigh again.

After weighing and immediately before adding snow, determine the temperature of the water estimating to the tenth of a degree.

Add *dry* snow slowly until the temperature of the water after the snow is melted is as far below room temperature as the beginning temperature was above room temperature. When sure that all the snow is melted, read and record the coldest temperature obtained.

Weigh the calorimeter and contents and compute the weight of snow melted.

Compute the number of calories given off by the hot water and by the calorimeter. (Specific heat of calorimeter, 0.1.)

Compute the number of calories received by the cold water formed from the melted snow. With x as the latent heat of snow, express the number of calories received by the snow when melting.

From the equation, heat given off is equal to the heat received, compute the latent heat of snow, or the number of calories required to melt one gram of snow.

Tabulation

Weight of calorimeter	....
Weight of calorimeter and water	....
Weight of water	....
Temperature of warm water	....
Weight of calorimeter, water, and snow	....
Weight of snow	....
Temperature of mixture	....
Calories given off by hot water	....
Calories given off by vessel	....
Calories received by cold water	....
Calories received by melting snow	....
Computed latent heat of snow	....
Correct latent heat of snow	....

Optional

If 10 pounds of ice at 32 degrees F. are placed in 11 pounds of water at 182 degrees F., the resulting temperature will be 42 degrees. Compute the latent heat of ice in British thermal units.

Place the boiler one-half filled on the tripod and screw the top on steam-tight. Connect the delivery or glass tube to the outlet of the boiler with a rubber tube.

Weigh the dry calorimeter to the nearest tenth of a gram.

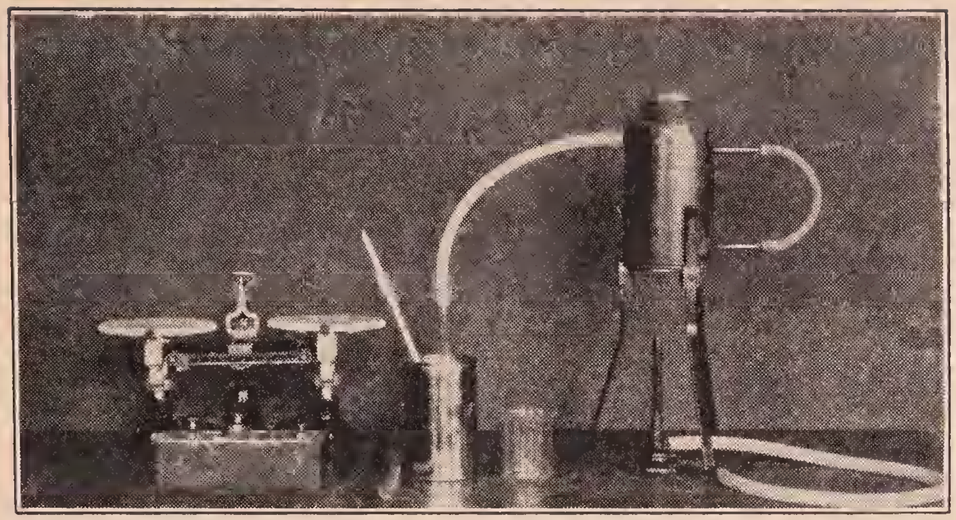
Fill the calorimeter about three-fourths full of the coldest water obtainable from the tap which should be about ten degrees below room temperature. Weigh the calorimeter and water to the nearest tenth of a gram.

When a strong jet is issuing from the delivery tube of the boiler, note accurately the temperature of the water in the calorimeter and immediately wipe the end of the delivery tube dry and plunge it nearly to the bottom of the water in the calorimeter.

Place the thermometer in the calorimeter using it and the delivery tube as stirring rods. When the temperature of the water is about as many degrees above room temperature as the cold water was below, remove the delivery tube with as little water as possible. Now watch the thermometer and record the highest temperature obtained.

Weigh the calorimeter and contents. The increase in weight will give the weight of the steam condensed. The temperature of the steam may be taken as 100 degrees Centigrade.

Compute the latent heat of steam, or the number of calories liberated as one gram of steam condensed. The heat received by the calorimeter (Sp. heat, 0.1) should be considered in the computation.



Tabulation

Weight of calorimeter	....
Weight of calorimeter and water	....
Weight of cold water	....
Weight of calorimeter, water, and steam	....
Weight of condensed steam	....
Temperature of steam	....
Temperature of cold water	....
Temperature of mixture	....
Rise of temperature, cold water	....
Fall of temperature, condensed steam	....
Latent heat of steam	....
Correct latent heat of steam	....

Optional

Two pounds of steam at 212 degrees F. condensed in 50 pounds of water at 40 degrees F. will raise the temperature of the water to 84 degrees F. Compute the latent heat of steam in British thermal units.

Clamp the Thorp gauge or gas meter in a vertical position. Connect the upper end of the gauge to a Bunsen burner and the lower end to a gas-cock. Observe that the instrument indicates the number of cubic feet passing through per hour.

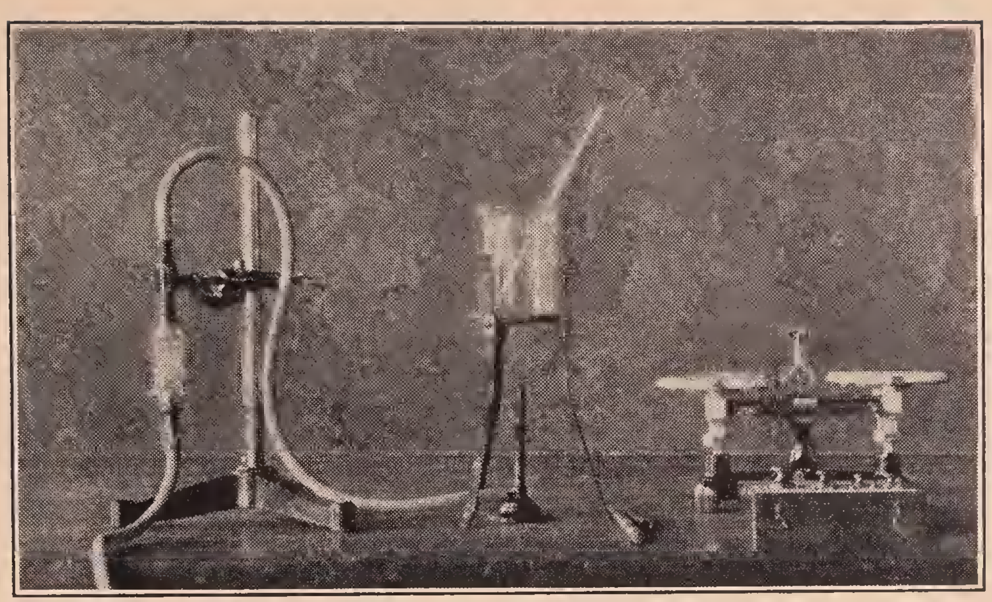
Weigh the glass vessel on the platform balance to the nearest gram. Fill the vessel about two-thirds full with water at about six degrees below room temperature and weigh again.

Light the burner and regulate the flow of gas to six cubic feet per hour. Determine the exact temperature, estimating to the tenth of a degree, of the cold water and immediately place the burner under the vessel.

After the water has been heating for exactly two minutes, remove the flame from underneath the vessel and determine the temperature of the water.

The fuel value of gas may be considered as 140,000 calories per cubic foot. Determine the amount of gas used during the two minutes and compute the number of calories equivalent or the input.

From the change of temperature, weight of vessel and weight of water used, compute the calories received by vessel and water or the output. (The specific heat of the vessel is 0.2.) Compute the efficiency of the gas burner.



TABULATION

Weight of glass vessel	....
Weight of vessel and water	....
Weight of water	....
Temperature of cold water	....
Resulting temperature	....
Calories received by water	....
Calories received by vessel	....
Output in calories	....
Reading of gauge	....
Time of heating	....
Cubic feet of gas burned	....
Input in calories	....
Efficiency of gas burner	....

OPTIONAL

With gas at 75 cents per 1000 cubic feet, find the cost of producing 1,000,000 calories of heat with a Bunsen burner.

Lay the magnet in the groove in the center of the magnet board and cover with a large sheet of paper. With the sieve box sprinkle iron filings evenly on the paper from a height of about a foot. A more even distribution of the filings will be obtained if the box is moved back and forth horizontally than if given a vertical shake. It is best not to use too many filings and to tap the board *gently* with the rubber stopper. Have the result accepted by the instructor.

First Method of Record

Draw in your notebook a diagram or picture of the magnet and iron filings as obtained on the paper. Draw the magnets about one-third size and represent the filings by short dashes.

Replace the filings in the box and repeat the process placing magnets in the two grooves with their unlike poles opposite.

For a third diagram place the like poles opposite.

Second Method of Record

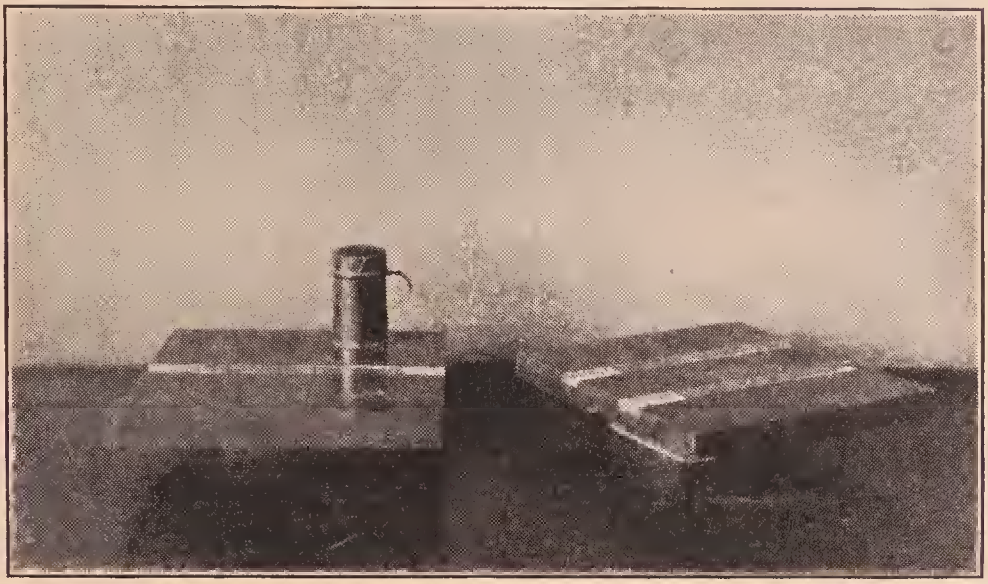
Replace the filings in the sieve box and cover the magnet with a sheet of blueprint paper, colored side up. The paper should be held in place and kept from curling by using thumb tacks at the corners or rulers on the edges. Sprinkle on filings as before. Place the apparatus in the direct sunlight and leave untouched for a period of from 45 to 60 seconds or until the uncovered portion of the paper has changed color considerably. Another test is to moisten the finger and touch the edge of the paper. If the paper turns to a decided blue, it is sufficiently exposed.

Pour off the filings and wash the paper in the water tank. When first placed in the water, the paper should be kept in motion for a few seconds. The washing should continue for six or seven minutes or until strong blue and white effects are obtained. When thoroughly washed, pin it up to dry.

Repeat the process placing magnets in the two grooves with their unlike poles opposite.

Repeat with like poles opposite.

When the prints are thoroughly dried, they are to be trimmed and inserted in the notebook.



1. For convenience of reference what name is given to the curves along which the filings have arranged themselves?

2. Each little filing as it falls near the large magnet becomes a small magnet and its position is determined by the resultant of the forces of attraction and repulsion. What definition may be given for the lines named in question 1?

3. Describe the direction of these lines in each of the three diagrams or prints.

Optional

Make a fourth trial and diagram using two magnets with unlike poles opposite. Place an iron washer on the board between the north and south poles of the two magnets. Why are there no lines of force above the washer?

Experiment 46 — ELECTROMOTIVE FORCES

Part I — Effect of Using Different Metals

Fill the glass jar about two-thirds full of the sulphuric acid solution. Connect two short wires to the binding posts of the porcelain holder. Clamp in the holder strips of copper and zinc that have been thoroughly polished with sand paper. Connect the exposed ends of the two wires to the binding posts of the voltmeter. The positive electrode of the cell must be connected to the positive binding post (right-hand side if not marked) of the voltmeter. When the voltmeter is reading correctly the polarity of the electrodes used in the cell may be determined by the connections.

Read and record the voltage. Repeat the test using a carbon strip in place of the copper. Continue the testing until all possible pairs of the five elements have been tried. Record the materials, polarity, and voltage in the manner suggested by the tabulation below.

Part II — Effect of Using Different Electrolytes

Determine the voltage when zinc and copper electrodes are immersed in the following electrolytes:

(*a*) dilute sulphuric acid
(*b*) dilute hydrochloric acid
(*c*) solution of common salt
(*d*) solution of sal ammoniac
(*e*) solution of sugar
(*f*) water from tap

The plates should be *very thoroughly* rinsed and wiped each time before placing them in a new liquid. Great care must be taken to see that each solution is returned to the proper bottle or jar.

Tabulation

Electrolyte	Pos. Electrode	Neg. Electrode	Voltage
....	....	....	....
....	....	....	....
....	....	....	....
....	....	....	....

From the results obtained, arrange the five elements in a column in such an order that each element will be negative in respect to all elements above it and positive to all elements below it. Such a column is called an electromotive series.

Optional

Effect of Size of Cell

Connect the simple cell (copper and zinc in sulphuric acid) to the voltmeter and record the voltage. Care should be taken to connect positive electrode (copper) to the positive (right-hand side if not marked) binding post of the meter. Move the plates as far apart as possible in the jar and record reading. Lift the plates one-half out of the liquid and record.

What conclusion can be stated concerning the relation between the size of the cell and the electromotive force?

Experiment 47 — RESISTANCE: AMMETER-VOLTMETER

Part I — Ohm's Law

Ohm's law states a relation between the voltage, amperage, and resistance. If the amperage of the current flowing through a resistance and the voltage causing it to flow are measured, the resistance can be computed by applying the law.

Connect the wire, the resistance of which is to be measured, a battery, a key, and an ammeter in series as shown in the diagram. For a battery use a small storage cell or two dry cells connected in series. Note that the meter may be used as an ammeter or a voltmeter depending on the binding posts used for the connections.

Close the key and record the reading of the ammeter, estimating tenths of a division. When using dry cells, take the reading when the pointer first comes to rest and immediately open the key.

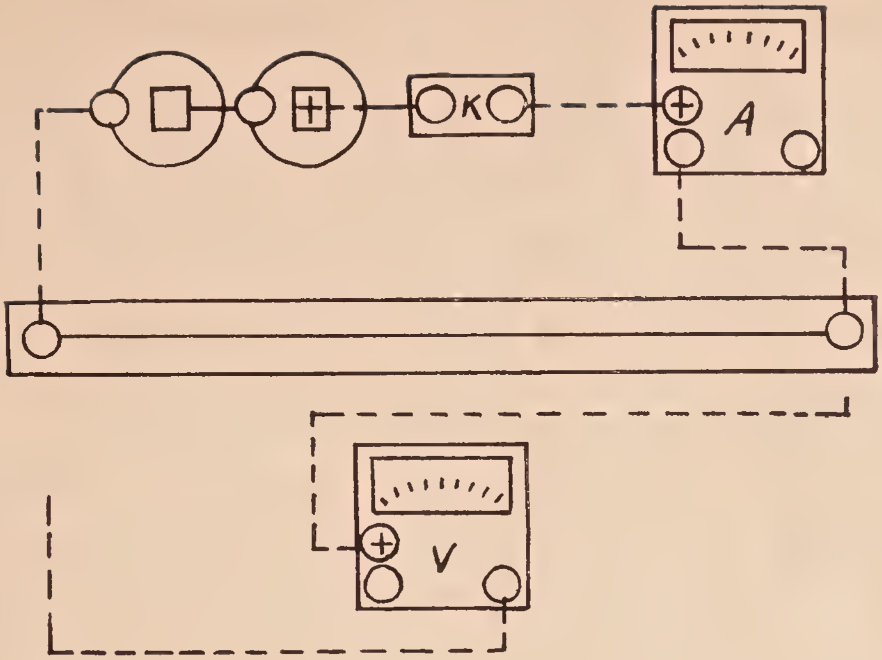
Disconnect the ammeter from the circuit and connect the key to the end of the wire. Connect the voltmeter as a shunt across the terminals of the wire. Record the reading of the voltmeter when the key is closed.

Part II — Specific Resistance

The resistance of a wire may be computed by multiplying the resistance of a mil foot of the wire by the length in feet and dividing by the square of its diameter in mils.

Measure the length in feet of the wire used in Part I. Use a micrometer screw and determine the diameter of the wire. If the screw reads in millimeters, change to inches and to mils.

Substitute this length and diameter and the resistance obtained in Part I in the above formula and solve for the resistance of a mil foot or the specific resistance of the alloy used in the wire.



Tabulation

Amperage through the wire	....
Voltage across terminals of wire	....
Resistance, computed (Ohm's law)	....
Length of wire (feet)	....
Zero reading of micrometer	....
Diameter of wire (millimeters)	....
Diameter of wire (inches)	....
Diameter of wire (mils)	....
Specific resistance	....

Optional

Compute the resistance of an aerial that has 100 feet of No. 14 aluminum wire. For necessary data see tables in Appendix.

The Wheatstone bridge consists of a divided circuit; each division contains two resistances. The current divides at A, a part flowing through R and X and a part through m and n. If a galvanometer is connected to C and to such a point D on the wire mn that no current flows through the galvanometer, then C and D are of the same pressure and by applying Ohm's law it can be shown that:

Resistance (X) : Resistance (R) :: Length (n) : Length (m).

Connect the apparatus as shown in the diagram. For the unknown resistance use a piece of German-silver wire No. 30 about four feet in length. After the wire is connected, determine the exact length of wire between the binding posts.

A Wheatstone bridge to be used correctly must have the point D somewhat near the middle of the wire mn, or a resistance near that of X must be placed in the resistance box R.

To determine the proper resistance for R, place in 10 ohms and note the direction of deflection of the galvanometer. (Care must be taken to close the battery circuit key first and then close, for a moment only, the galvanometer circuit key at the point D.)

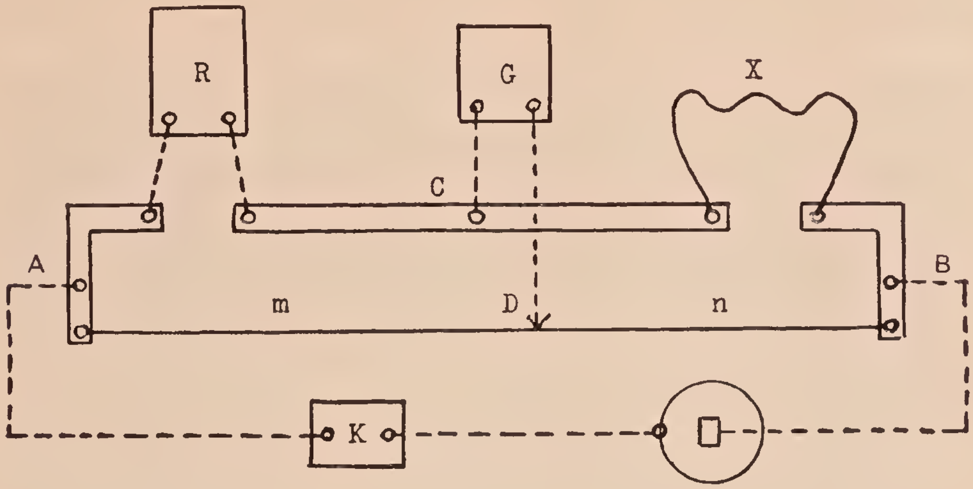
Place 100 ohms in R. If the deflection is in the same direction, the proper resistance is below 10 ohms; but if the direction of deflection changed then more resistance is needed in R. Start again with 10 ohms in R and change by one ohm at a time until the direction of deflection changes. The last resistance tried is sufficiently near X to be considered the proper resistance for R.

See that all points of contact, binding posts and plugs, are tight and make final adjustment by moving the contact point D back and forth on the wire until a point is found where closing both keys no deflection is obtained.

Record the resistance R and the lengths of the portions of the wire m and n. Substitute in the bridge formula and solve for the unknown resistance X.

Determine by means of a micrometer screw, the diameter of the wire X in millimeters. Change to inches and record

in mils. Substitute the length of the wire in feet, the resistance found in ohms, and the diameter in mils in the resistance formula and solve for the specific resistance of German silver.



Tabulation

Length of German-silver wire	.... ft.
Resistance in box R	.... ohms
Length of wire (m)	.... mm.
Length of wire (n)	.... mm.
Resistance of wire (X)	.... ohms
Diameter of German-silver wire	.... mm.
Diameter of German-silver wire	.... in.
Diameter of German-silver wire	.... mils
Specific resistance of German silver	.... ohms

Optional

Apply Ohm's law to the four parts of the circuit: A to C, C to B, A to D, D to B, and prove the bridge formula (X : R :: n : m).

Note: If C and D are of the same pressure then the voltage between A and C must be equal to the voltage between A and D and likewise between C and B and between D and B.

Experiment 49 — SERIES CIRCUIT

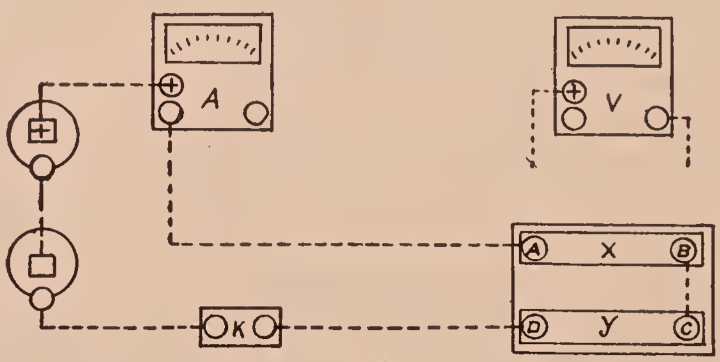
Part I — Amperage

Connect the ammeter, the two rows of resistance coils of a resistance box, a key, and a battery all in series as shown in the diagram. For the battery use two dry cells connected in series.

Remove the three-ohm plug from one row of resistances and a one-ohm plug from the other row. The other plugs should be firmly placed which can be done by giving them a partial turn under slight pressure. (Loosen all plugs when through with the experiment.)

Close the key and take as the ammeter reading the point where the pointer first comes to rest. When using dry cells, never keep the key closed any longer than is absolutely necessary to secure the reading.

For convenience we speak of the current as coming from the positive terminal of the battery. Connect the ammeter between the key and the negative terminal of the battery and again determine the amperage of the circuit.

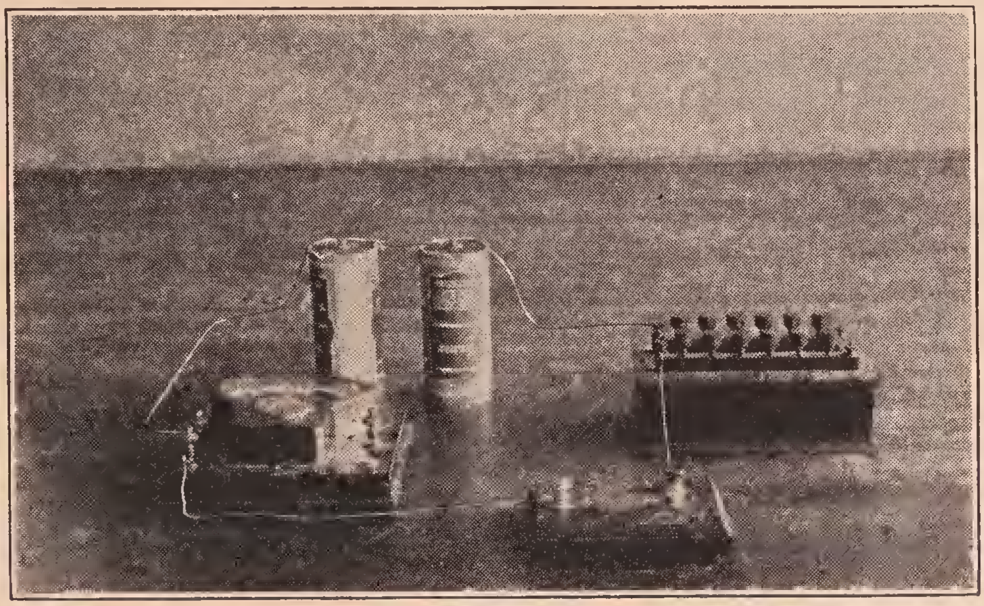


Part II — Voltage

Disconnect the ammeter from the circuit. Use the voltmeter binding posts of the meter and connect as a shunt across the terminals (A and B) of the one-ohm resistance. Close the key and read the voltmeter.

Connect the voltmeter across the terminals (C and D) of the three-ohm resistance and determine the voltage. Now connect the voltmeter as a shunt to both resistances in series (between A and D).

From the amperage of the circuit and the voltage between A and D, apply Ohm's law and compute the resistance of the circuit from A to D. Apply Ohm's law to the partial circuits A to B and C to D and compute the resistance in each.



TABULATION

Amperage at pos. terminal	....
Amperage at neg. terminal	....
Voltage between A and B	....
Voltage between C and D	....
Voltage between A and D	....
Resistance between A and B (x)	1 ohm
Resistance between C and D (y)	3 ohms
Resistance between A and D ($x + y$)	4 ohms
Resistance (x) by Ohm's law	....
Resistance (y) by Ohm's law	....
Resistance ($x + y$) by Ohm's law	....

State conclusions that can be drawn concerning amperage, voltage, and resistance of a series circuit.

What relation is shown between the voltage drop and the resistance along a series circuit?

OPTIONAL

Make a neat diagram (use ruler) of the circuit showing all connections of ammeter and voltmeter made in the experiment.

Part I — Amperage

The two rows of resistance coils in the resistance box are to be used as two separate resistance boxes (x and y). Connect a battery of two dry cells in series, the ammeter, a key, and the resistances in a circuit as shown in the diagram. Note that the current divides: a part goes through the resistance x and a part through the resistance y.

Place one ohm in the x division and three ohms in the y division. Read and record the reading of the ammeter. This will be the amperage in the main circuit.

Disconnect the ammeter from the main circuit and connect it between the key and the resistance x. This reading or amperage will be the part passing through the one ohm. In a like manner connect the ammeter so as to determine the amperage of the current flowing through the three ohms.

Part II — Voltage

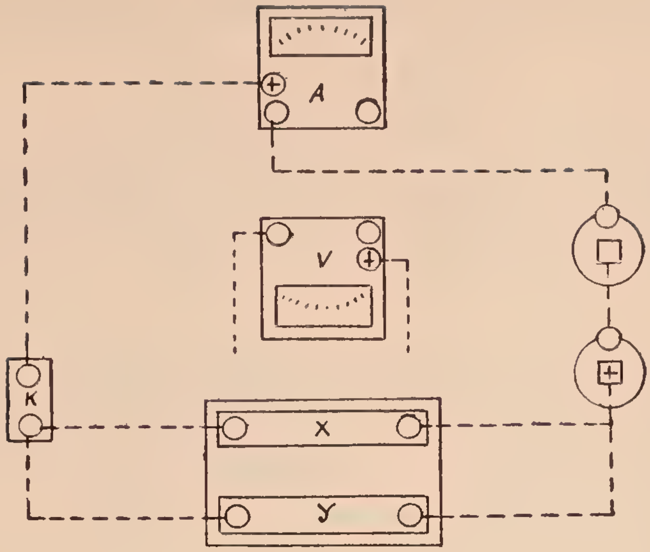
Connect the battery, key, and resistance boxes as in Part I. Use the meter now as a voltmeter and connect to the terminals of x. Close the key and determine the voltage or pressure causing the current to flow through the one ohm.

Connect the voltmeter so as to determine the voltage causing current to flow through the three ohms.

Part III — Resistance

Compute the joint resistance of x and y, or a single resistance that would have the same effect in the circuit, by applying Ohm's law. (Divide the voltage across the parallel circuit by the sum of the currents in the two branches.)

The resulting resistance of two parallel circuits can be obtained by the formula: R equals the product of the individual resistances divided by their sum.



Tabulation

Amperage of main circuit	....
Amperage of x branch	....
Amperage of y branch	....
Voltage across x branch	....
Voltage across y branch	....
Resistance in x circuit	....
Resistance in y circuit	....
Resistance of x and y (Ohm's law)	....
Resistance of x and y (Formula)	....

State the relation between the resistances and the amperages of a divided circuit.

State a conclusion concerning the voltage causing the current to flow through to the different resistances in parallel.

How could the magnitude of a single resistance that would take the place of two resistances in parallel be computed?

Optional

Make a neat diagram of the circuit showing all connections of ammeter and voltmeter made in the experiment.

Experiment 51 — BATTERY CONNECTIONS

Part I — Voltage

Determine the voltage of each of three dry cells by connecting them individually to the voltmeter binding posts of the meter.

Connect two of the cells in series, that is, connect the zinc of one to the carbon of the other and the remaining zinc and carbon to the voltmeter. In a like manner find the voltage of the three cells when connected in series.

Connect two of the cells in parallel, that is, zinc to zinc and carbon to carbon with a zinc connection to one post and a carbon connection to the other post of the voltmeter. In a like manner find the voltage of the three cells when connected in parallel.

Part II — Amperage

Connect two cells in series. Place in the external circuit an ammeter, key, and resistance box. Determine the amperage with each of the following resistances in the circuit: 10, 5, 0.2, 0.1 ohms.

The key should be closed only while taking a reading of the meter. The position where the pointer first comes to rest should be taken as the reading.

Change the connections of the two cells from series to parallel. Find the amperages obtained with the same individual resistances in the external circuit.

What general conclusions can be drawn concerning the voltage of series and parallel batteries? When is it better to connect in series? In parallel?

Tabulation

Part I — Voltage

Arrangement of Cells	Voltage
Single cell, No. 1	....
" " No. 2	....
" " No. 3	....
Two cells in series	....
Three cells in series	....
Two cells in parallel	....
Three cells in parallel	....

Part II — Amperage

Battery	External Resistance	Amperage
Two cells in series	10 ohms	....
" " " "	5 "	....
" " " "	0.2 "	....
" " " "	0.1 "	....
Two cells in parallel	10 "	....
" " " "	5 "	....
" " " "	0.2 "	....
" " " "	0.1 "	....

Optional

Find the voltage of four cells connected in multiple series. Arrange the four cells in two rows, each consisting of two cells in series. The rows are connected in parallel.

Experiment 52 — TERMINAL VOLTAGE AND RESISTANCE OF CELL

Part I — Terminal Voltage

Connect the terminals of a dry cell to the binding posts of a voltmeter and record the reading. This is called the electromotive force (E) or open circuit voltage of the cell.

Leave the voltmeter connected to the cell and connect also to the binding posts of the cell a second (external) circuit containing a key and a resistance box. If the key is closed, the voltmeter will give, not the voltage of the cell, but the voltage used to force the current through the external circuit. Record the reading when the key is closed as the terminal voltage (V).

Place 100 ohms in the resistance box or external circuit. Close the key and record the terminal voltage. Repeat with 0.1 ohm in the box. Give reasons for the results obtained.

Part II — Resistance of Cell

Use apparatus as connected in Part I, except that the battery should be three dry cells connected in series. Determine the terminal voltage when each resistance given in the tabulation below is placed in the resistance box or external circuit. Before each trial and while the key is open, read and record the electromotive force.

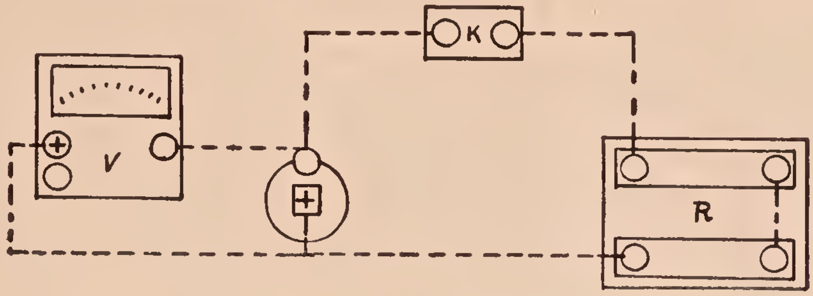
If Ohm's law is applied to the entire circuit

$$\text{Amperage} = \frac{\text{Electromotive force of battery (E)}}{\text{Ext. Resist. (R)} + \text{Int. Resist. (r)}}$$

If the law is applied to the external circuit only

$$\text{Amperage} = \frac{\text{Terminal voltage (V)}}{\text{External resistance (R)}}$$

As the amperage is the same through the circuit, equate the last members of the above equations and derive a formula for (r). Compute r in each of the trials. From the average determine the internal resistance of one dry cell.



TABULATION

PART I — TERMINAL VOLTAGE

Electromotive force of cell	....
Terminal voltage (V) with 100 ohms	....
Terminal voltage (V) with 0.1 ohms	....

PART II — RESISTANCE OF CELL

EXT. RESIST. (R)	E.M.F. (E)	TER. VOLT. (V)	INT. RESIST. (r)
1.7 ohms	....	....	....
1.4 ohms	....	....	....
1.0 ohms	....	....	....
.7 ohms	....	....	....
.4 ohms	....	....	....
Average resistance of one dry cell			....

OPTIONAL

What is the line drop or voltage drop per mile in a trolley line carrying 150 amperes, if the line is No. 1 copper wire?

Experiment 53 — ELECTROMAGNETISM

Part I — Thumb Rule

Connect an electrode of a dry cell to one binding post of the key by means of a copper wire about three feet long. Complete the circuit from key to battery with a short wire.

Place some portion of the long wire parallel to and above the magnetic needle of a compass so that the current will flow from the south to the north. Record the deflection of the north pole (east or west) when the key is closed.

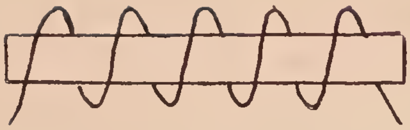
Determine the deflection of the north pole when the current is going in the different directions and locations indicated in the table below. In the last four determinations the compass should be placed on the end of a block of wood and the wire held in a vertical position.

Represent each of the last four trials with a diagram. Represent the cross-section of the wire by a small circle. If the current is coming up, place a dot in the circle; if going down, place a cross in the circle. Draw the needle near the circle showing its exact position in relation to the wire and the direction of the N pole when the current was passing.

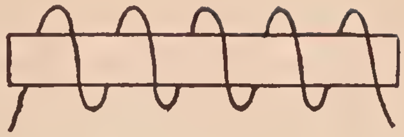
Tabulation

Direction of Current	Deflection of N Pole
Going north above needle	....
Going north below needle	....
Going south above needle	....
Going south below needle	....
Going up near N pole	....
Going up near S pole	....
Going down near N pole	....
Going down near S pole	....

State a hand rule that expresses the relation between direction of current and the deflection of the N pole. Apply the rule to the first four trials in the table. When grasping the wire, the fingers must be on the same side of the wire as the needle.



A



B

Form a close wound coil by wrapping the longer wire ten or twelve times around a soft iron nail. Place the coil in an east and west direction with one end near the side of the compass. Note the direction of the needle when the current is flowing.

Draw a diagram of the coil and needle. Indicate the direction of current by means of arrows and label the north pole. Notice which type of winding (A or B) is used in making the coil.

Place the compass at the other end of the coil. Note the position of the needle when the key is closed. Represent this needle in the drawing. State the thumb rule for electromagnets and apply it as a check to the drawing.

OPTIONAL

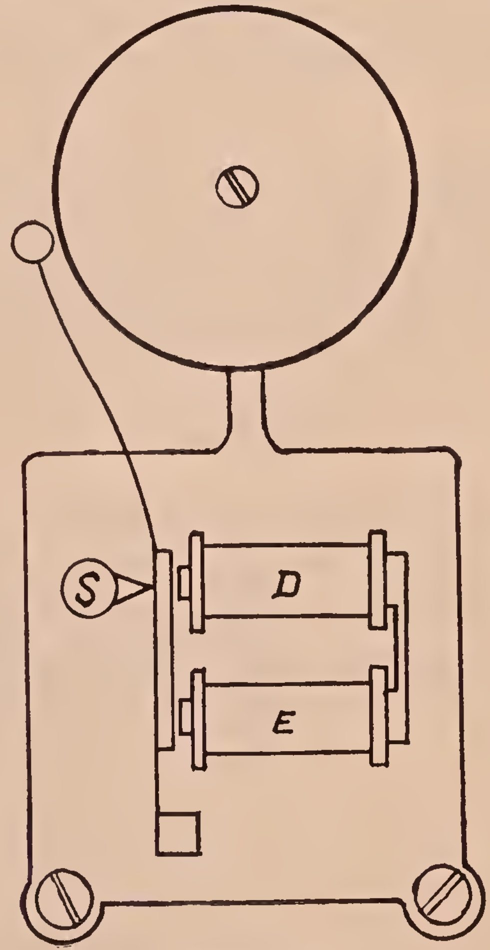
Connect the two binding posts of the key to the two outlets underneath the edge of the table or to some other assigned source of direct current. Place some part of the wire above the compass and note the deflection when the key is closed. By the rule stated above determine the polarity of the outlets or source.

Experiment 54 — ELECTRIC BELL

Remove the iron cover from the bell. Beginning at one of the binding posts, trace the path of the current by way of the coils of wire and other connections to the other binding post.

Draw a skeleton diagram (similar to the one here shown) of the parts of the bell. Represent a few turns of wire around the cores of the electromagnets in the proper direction. Represent the path of the current through other wire connections by means of lines. Where the current passes through metal parts indicate its path by small arrows.

Write a concise description or explanation of how the hammer of the bell is kept in vibration.



OPTIONAL

Connect a bell, two keys, and a dry cell in such a way that closing either key will ring the bell. Show these connections in your notebook by a diagram. This will represent connections when front and rear buttons ring the same bell.

Show by diagram the connections when each button rings a separate bell with but one battery.

Experiment 55 — TELEGRAPHY

1. Explain the action in the receiver when the circuit is closed by pressing the key down in the transmitter.

2. Explain the action in the receiver when the circuit is opened by the transmitter.

3. Explain how the dot and the dash are produced by the transmitting operator.

4. Explain how the dot and the dash are recognized by the receiving operator.

5. Explain the purpose of the switch on the transmitter.

With the student on the opposite side of the table, set up a telegraph system of two stations. For the line wire use a long piece of insulated wire. Use support rods and clamps for telegraph poles. Connect to gas-cock for ground circuit.

Place in your notebook a neat and labeled diagram of your apparatus and connections.

Try communication with the Morse Code.

A	. —	H	. . . .	O	— — —	V	. . . —
B	— . . .	I	. .	P	. — — .	W	. — —
C	— . — .	J	. — — — —	Q	— — . —	X	— . . —
D	— . .	K	— . —	R	. — .	Y	— . — —
E	.	L	. — . .	S	. . .	Z	— — . .
F	. . — .	M	— —	T	—		
G	— — .	N	— .	U	. . —		

Optional

Use a relay and connect a local circuit of sounder and battery at one station.

Experiment 56 — ELECTROLYSIS

Part I — Copper Plating

By means of a voltmeter determine the positive terminal of the source of current that is to be used in the experiment. (A small motor-generator, storage cell, or three dry cells connected in series may be used as the source.) If the current is supplied through outlets on the table, the positive of the source may be indicated as east or west, right or left.

Fill the tumbler or jar of a student demonstration battery half full of a solution of copper sulphate. Place in the holder a rod of carbon and a strip of copper. Connect the electrodes to the current source in such a manner that the current will pass from the copper to the carbon.

Let the current pass for one minute and describe the action taking place on each electrode.

Change the connections at the source so that the current will pass from the carbon to the copper. Describe the action taking place on each electrode.

In each test what must have been the relation between the direction of the current and the direction of the movement of copper ion?

Tabulation

Position of positive of current source	....
Current passes from copper to carbon	
Effect on carbon electrode	....
Effect on copper electrode	....
Current passes from carbon to copper	
Effect on carbon electrode	....
Effect on copper electrode	....
Direction of copper ion movement	....

Fill the battery jar half full of ten per cent solution of sulphuric acid. Place in the holder two well sandpapered strips of lead. Connect the lead electrodes to the voltmeter and determine if there is any voltage.

Mark one of the lead plates P and the other plate N. Connect the plates to the source of current in such a manner that the current will enter at the positive plate. Let the current (charging current) flow for one minute. Examine the plates and describe the effect, if any, on each plate.

Connect the charged cell to the voltmeter and determine the direction of the discharging current through the cell. Record the voltage of the storage cell.

Leave the cell connected to the voltmeter until it is completely discharged. Examine the plates and describe the changes, if any, on each plate.

Tabulation

Voltage of two lead plates in acid	....
Direction of charging current in cell	....
Change on P plate during charge	....
Change on N plate during charge	....
Direction of discharging current in cell	....
Voltage of charged storage cell	....
Change on P plate during discharge	....
Change on N plate during discharge	....

Optional

Conductivity of Water

Fill the tumbler or battery jar with tap water. Place two copper plates in the holder. Connect the cell and an ammeter in series with the source of current. Does any current flow? Sprinkle salt in the water and watch the ammeter. Explain.

Weigh the metal vessel on a platform balance to the nearest tenth of a gram. Weigh the vessel one-half full of water four or five degrees below room temperature.

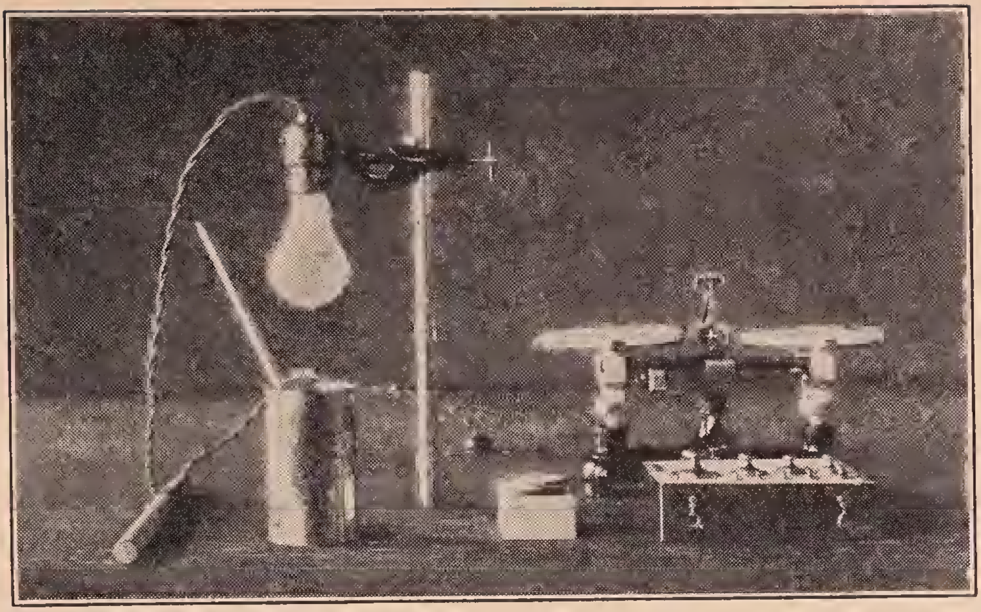
Determine the amperage of a 60-watt lamp by connecting it in series with an A.C. ammeter of one-ampere range. To measure the voltage connect the voltmeter to the terminals of the lamp socket. If the proper meters are not available, satisfactory results may be obtained by using the wattage given on the lamp.

By means of a large universal clamp support an electric-light socket in a vertical position so that the lamp can be raised or lowered on the support rod.

Take the exact temperature of the water and lower the lamp into the vessel until the brass base is just above the surface of the water. Connect the lamp to the A.C. outlet on the table and pass current through the lamp for exactly three minutes. Record the resulting temperature.

Compute the number of calories received by the water and by the vessel. (Specific heat of the vessel is 0.1.) Record the total number of calories received as the output.

From the wattage and time compute the number of watt-seconds or joules. From the heat equivalent of an electric current compute the input or the number of calories generated by the number of watt-seconds used. Compute the efficiency of the lamp as an electric heater.



Tabulation

Weight of metal vessel	....
Weight of vessel and water	....
Weight of water	....
Temperature of cold water	....
Temperature resulting	....
Calories received by vessel	....
Calories received by water	....
Calories received, output	....
Amperage of lamp	....
Voltage of lamp	....
Wattage of lamp, computed	....
Time of current flow	....
Watt-seconds, joules	....
Calories generated, input	....
Efficiency of electric heating	....

Optional

Obtain the local cost of electric energy per kilowatt-hour (lowest rate) and determine the cost of operating the lamp for three minutes or the cost of the number of calories received. At the same rate compute the cost of obtaining 1,000,000 calories and compare with the cost of obtaining 1,000,000 calories with a gas heater determined in a previous experiment.

Experiment 58 — ELECTROMAGNETIC INDUCTION

(*a*) Cause of Induction

With a piece of insulated wire, No. 18, about six feet in length, make a coil of twenty turns by wrapping it around a cylinder of about one-inch diameter. Connect the ends of the wire or coil to the galvanometer. Move a magnet in and out of the coil and note the effect on the galvanometer. Note if current is produced when the magnet is not moving.

State the action or conditions necessary to produce an induced current.

(*b*) Magnitude of Induced Electromotive Force

Note the magnitude of the deflection of the galvanometer as a magnet is thrust into or pulled out of the coil. Note the magnitude of deflection when the number of lines of force is increased by using two magnets with like poles together. Note the effect on the magnitude of the deflection when the speed of the movement of the magnet is changed.

State what determines the magnitude of the induced current.

(*c*) Direction of the Induced Current

Turn the coil and galvanometer so that you are facing one end of the coil. Thrust the N pole of the magnet into the coil and determine from the deflection of the galvanometer the direction of the current induced in the coil. (The needle of the galvanometer moves toward the binding post at which the current enters.) Record direction as clockwise or counterclockwise. Record the direction of current as the magnet is pulled out. Repeat using S pole.

While current is being induced in the coil it is an electromagnet. Apply the thumb rule and determine the polarity of the end of the coil approached by the N pole of the magnet. Explain how this result proves Lenz's law.

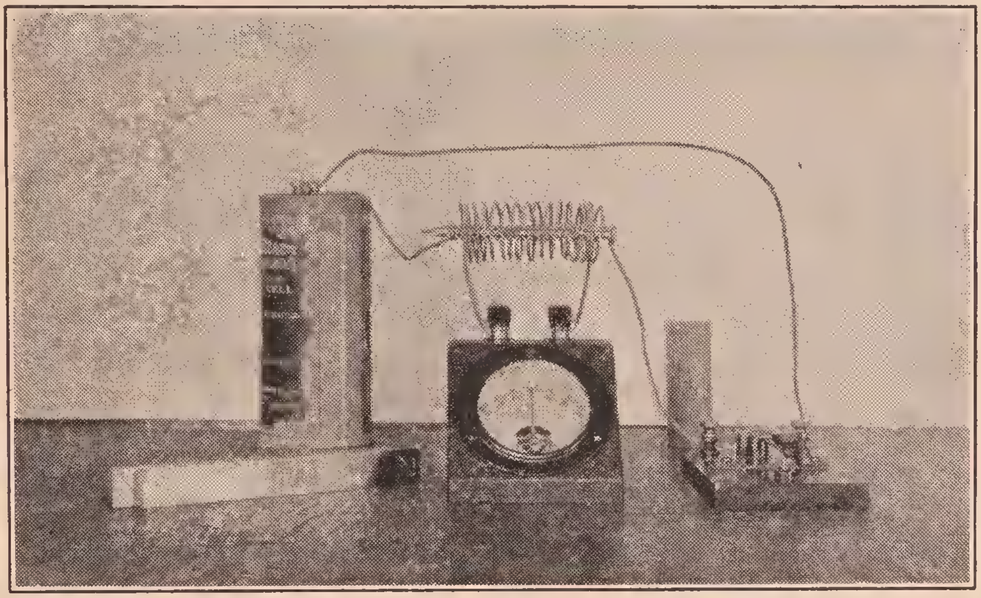
(*d*) Induction from an Electromagnet

With a piece of wire about three feet in length make a coil of ten turns around a wire nail. Place this coil and nail within the other coil. Connect a cell and key in series with the inner coil. Face one end of the coils and record the direction

of the induced current at the instant the key is closed; when it is opened.

Make connections at the battery so that the current will flow through the primary in a clockwise direction. Record the direction of current in the secondary when the key is closed. Repeat with the current counterclockwise in the primary.

State the relative directions of the primary and secondary currents. Explain how this is a proof of Lenz's law.



TABULATION

(FOR *c* AND *d*)

ACTION	DIRECTION OF INDUCED CURRENT
N pole thrust into coil	....
N pole pulled out of coil	....
S pole thrust into coil	....
S pole pulled out of coil	....
Primary circuit closed	....
Primary circuit opened	....
Primary current clockwise	....
Primary current counterclockwise	....

OPTIONAL

Determine the effect on the magnitude of the induced current when the nail is partly removed and when it is entirely removed from the primary coil. Explain.

Experiment 59 — STUDY OF DYNAMOS

Study the model and observe the three essential parts of a dynamo: the field, or means of producing the magnetic field; the armature, or part that rotates and cuts the magnetic lines of force; the collectors, or the means of connecting the armature circuit with the external circuit.

There are two types of collectors. To change from one armature and collector to the other, turn up or raise the central top screw (screw driver not needed) about five millimeters. Then raise the armature out of its lower socket and carefully remove it at the side. When an armature is replaced, turn down the top screw until the armature is held in position and can rotate freely without friction.

Part I — Magneto

Place the armature with the two separate rings in position and adjust the brushes so that each one is in contact with a different ring. Place the permanent bar magnets in the clamps with a north and a south pole near the armature. The apparatus now represents a magneto.

(*a*) Connect the brushes to a galvanometer. Rotate the armature very slowly and determine the points at which the current reverses. Explain why the current reverses.

(*b*) Note the number of times the current reverses in one rotation of the armature and state what determines the number of alternations per minute or the frequency.

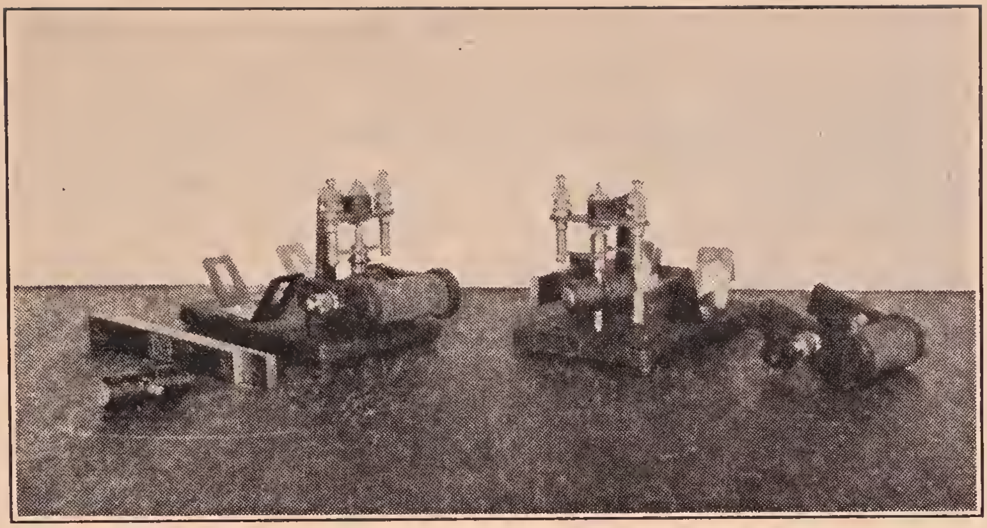
Part II — Alternating Current Generator

Remove the bar magnets and place in position the electromagnet field coil. In series with the coil place a dry cell, a resistance box with the one-ohm plug removed and a key. The apparatus now represents a separately excited A.C. generator.

(*a*) With the key open, rotate the armature and note the magnitude of the galvanometer deflection. What is the source of the lines of force now being cut?

(*b*) Repeat the test with the key closed while the armature rotates. What is the cause of the change in the magnitude of the current produced?

(*c*) Rotate the armature at different speeds. State the two factors discovered that determine the magnitude of the voltage of a generator.



PART III — DIRECT CURRENT GENERATOR — SERIES-WOUND

Remove the resistance box and cell. Replace the armature with the two-ring collector with the armature having a single ring divided into two segments (commutator). Connect the field coil, the brushes or armature, and the galvanometer or external circuit in series to represent a series-wound D.C. generator.

(*a*) Rotate the armature and note the kind and direction of the current produced. Rotate the armature in the other direction.

(*b*) Rotate the armature slowly and note what change takes place in the commutator when the armature passes through the points at which the current was found to alternate in Part I.

PART IV — DIRECT CURRENT GENERATOR — SHUNT-WOUND

To represent a shunt-wound generator, connect the field coil in parallel with the galvanometer or external circuit so that the current from the armature will divide at the brushes, a part going through the field and a part through the external circuit.

Have the connections accepted by the instructor.

OPTIONAL

Make proper connections to have the apparatus operate as a compound wound generator. For the series field coil use a short piece of drop cord and wind it four or five times around the field electromagnet. Have the connections accepted by the instructor.

Experiment 60 — STUDY OF ELECTRIC MOTORS

As a direct current generator may be used as a direct current motor, a motor may be considered as having the same three essential parts.

Part I — Cause of Rotation

Remove the permanent magnets or electromagnet from the field. Use the armature with a commutator and rotate it to such a position that it will be diagonal to the base of the instrument. Connect a dry cell and key in series with the brushes. By means of a compass determine the polarity of the armature coil when the key is closed.

Place the permanent magnets in the clamps with a south and a north pole near the armature. Which way does the armature rotate when the current is passed? Explain cause of rotation.

Part II — Action of Commutator

Rotate the armature by hand and observe what happens on the commutator at the same time that the pole of the armature passes an unlike pole of the field. Explain why the armature of a motor continues to rotate.

Part III — Direction of Rotation

Remove the bar magnets and place in position the electromagnet field coil. Connect field, armature, key and cell in series to represent a series-wound motor.

(*a*) State the direction of rotation of the armature as clockwise or counterclockwise.

(*b*) Change the direction of the current by changing the battery connections. State direction of rotation.

(*c*) Change the direction of the current through the field only and state direction of rotation.

(*d*) How can the direction of an electric-motor-driven vehicle be reversed?

Part IV — Speed of Rotation

Set up the apparatus as a shunt-wound motor by connecting the field parallel to the armature or so that the current will divide at the brushes, and a part will pass through the field and a part through the armature.

Place a resistance box in the external circuit and note the speed of the armature rotation as different resistances (0.1, 0.3, 0.5, 0.7, ohm) are placed in the circuit.

Explain how the speed of rotation of an electric motor may be controlled.

Optional

Back Electromotive Force

Connect field, armature, key and cell in series as in Part III. Make note of the direction of the armature rotation and the direction of the battery current through the armature.

Disconnect the battery and key from the motor and connect the galvanometer as the external circuit. Rotate the armature by hand in the same direction that it rotated as a motor. Determine by the galvanometer the direction of the current produced in the armature. (The pointer of the galvanometer moves toward the binding post where the current enters.)

How is the current generated in the armature and the current supplied by the cell related in direction? What is the generated pressure called? What effect does it have on the current drawn by the motor?

Experiment 61 — HORSEPOWER OF AUTOMOBILE

Part I — S.A.E. Formula

The relative horsepower of automobile engines is often determined by means of a formula known as the S.A.E. or Society of Automotive Engineers formula: Horsepower equals the square of the diameter of the cylinder in inches times the number of cylinders divided by 2.5.

From the Table of Chassis Specifications given in the Appendix select the car to be studied. Determine the number of cylinders and the diameter of cylinder or bore. Substitute in the S.A.E. formula and compute the horsepower of the engine.

Part II — Brake Horsepower Formula

By definition horsepower is obtained by dividing the work done per minute (force $\times$ distance) by 33,000. In a gas engine the force would be the average pressure for the stroke times the area of the piston. The distance would be the stroke times the number of power strokes per minute, or the piston speed in feet per minute divided by four. If this were multiplied by the number of cylinders and by the mechanical efficiency of the engine, the actual or brake horsepower would be obtained.

(Brake H.P. equals $P \cdot A \cdot S \cdot N \cdot E$ divided by $33{,}000 \times 4$.)

Experiment has shown that the average cylinder pressure is 90 lb., to the square inch, and the average efficiency 75 per cent. Assuming that the car is running at such a velocity that the piston speed is 1000 feet per minute, substitute in the above equation and solve for horsepower. Compare this result with the other and state conclusion.

Tabulation

Part I

Make of car selected	....
Diameter of cylinder (bore)	....
Horsepower, S.A.E. formula	....

Part II

Pressure, average for stroke	....
Area of piston, sq. in.	....
Speed of piston, ft. per min.	....
Number of cylinders	....
Efficiency of engine	....
Horsepower, brake formula	....

Optional

The brake horsepower curve shown in Experiment 62 gives the horsepower at different revolutions per minute obtained by actual test on a six-cylinder engine, three and one-eighth inch bore, four and one-half inch stroke.

Apply the S.A.E. formula and compute the horsepower.

The S.A.E. formula is true only when the piston speed is 1000 feet per minute. From the stroke compute the revolutions per minute (R.P.M.) of the engine when the piston speed is 1000 feet per minute. From the horsepower curve determine the horsepower of the engine at that speed.

Diameter of cylinder (bore)	....
Number of cylinders	....
Horsepower, S.A.E. formula	....
Length of piston movement (stroke)	....
R.P.M. at 1000 F.P.M. piston speed	....
Horsepower at above R.P.M.	....

Compare the horsepower obtained by formula with the horsepower obtained by actual test and state conclusion concerning the value of the S.A.E. formula.

Torque is the ability of a force to produce rotation and is measured by the product of the force and the perpendicular distance from the line of action of the force to the center of rotation.

The unit of torque is the pound foot. It is the torque of a force of one pound acting at a distance of one foot.

In the "brake test" of an engine, the horsepower is obtained by the formula:

$$\text{Horsepower} = \frac{\text{Force} \times 3.1416 \times 2 \times \text{Radius} \times \text{R.P.M.}}{33{,}000}$$

The torque can be obtained from the same test by the formula:

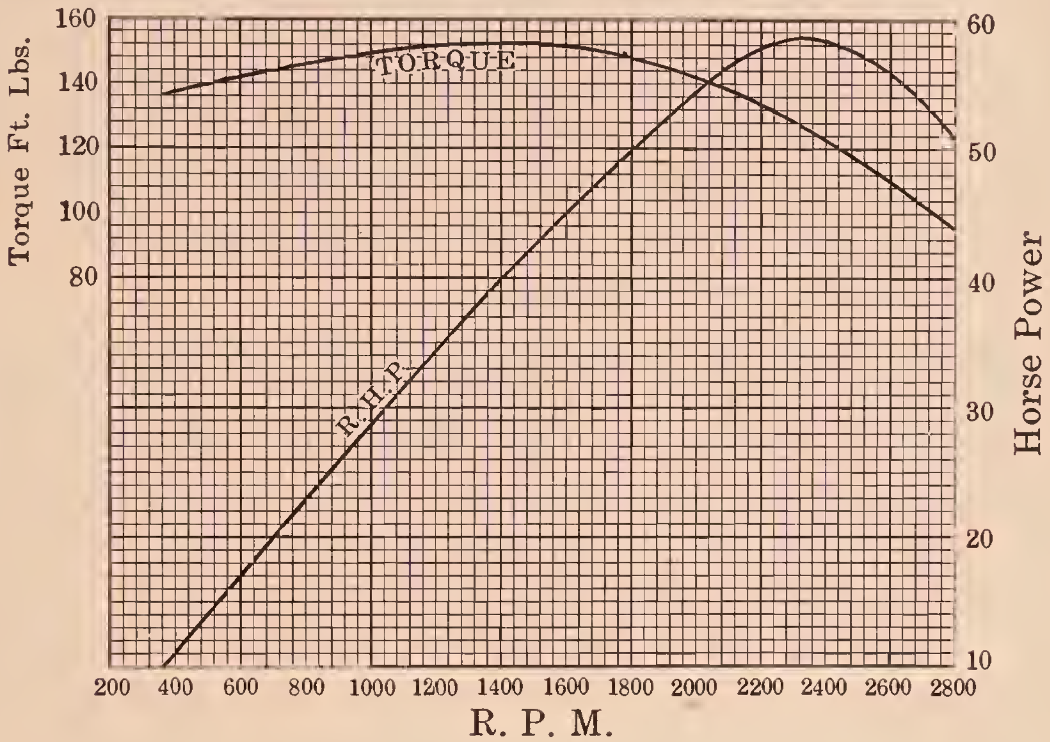
$$\text{Torque} = \text{Force (pounds)} \times \text{Radius (feet)}$$

In each of the above formulas obtain a formula for force in terms of the other factors. As it is the same force in each formula, equate the two quantities and obtain a formula for torque in terms of horsepower, R.P.M., and one numerical quantity.

With this formula compute the torque of the Nash 8–80 engine at each speed given in the following table:

R.P.M.	Horsepower	Torque
600	18.5	....
900	27.5	....
1200	36.5	....
1500	45.5	....
1800	54.6	....
2100	64.0	....
2400	73.0	....
2700	80.0	....
3000	85.0	....
3300	87.0	....
3500	86.0	....

On double-ruled or cross-section paper plot the horsepower curve showing the relation between horsepower and the number of revolutions per minute. On the same paper plot the torque curve showing the relation between the pound-feet and the revolutions per minute.



Optional

From the Table of Specifications given in the Appendix, obtain the gear ratio and size of rear tires of the car studied above and compute the speed of the car in miles per hour at the R.P.M. of the crankshaft when the engine is at its maximum torque.

Power equals force $\times$ velocity (ft. per min.).

Horsepower equals force $\times$ velocity divided by 33,000.

Neglecting the loss in transmission, the power of the driving or rear wheels of a car will be the same as the engine. If the last equation is applied to the rear wheels, the horsepower of the wheels may be considered as that of the engine less ten per cent due to loss of transmission. The velocity of the wheel is the given velocity of the car and the force factor is the push exerted by the rear tires against the road and is called the road thrust.

From the Table of Chassis Specifications given in the Appendix, obtain the gear ratio and diameter of rear wheel of the car studied in Experiment 62. From the diameter of the wheel compute the circumference. From the circumference of the wheel compute the number of revolutions per minute (R.P.M.) of the rear axle when the car is going 25 miles per hour. From the R.P.M. of the axle and gear ratio when in high, compute the R.P.M. of the engine at 25 miles per hour.

Study the horsepower curve of the engine and find H.P. at the computed R.P.M. when going 25 miles per hour. Substitute tire velocity and H.P. of tire in the equation and solve for force or road thrust.

Find the gear ratio of car when in second speed and compute the road thrust at 25 miles per hour. The loss in transmission should now be considered 15 per cent. It is greater because of transmission through the countershaft.

From the results of this study, state the reason for shifting to a lower gear when climbing a hill.

Tabulation

Position of Shift Lever	High Speed	Second Speed
Name of car considered	....	....
Gear ratio	....	....
Diameter of rear wheel	....	....
Circumference of rear wheel	....	....
R.P.M. of rear axle at 25 M.P.H.	....	....
R.P.M. of crankshaft at 25 M.P.H.	....	....
H.P. of engine at above R.P.M.	....	....
H.P. of rear axles at above R.P.M.	....	....
Road thrust of wheels at 25 M.P.H.	....	....

Optional

Determine the road thrust of the same car when going fifty miles an hour in high gear.

The essential parts of the electric system of an automobile may be divided into five distinct circuits: The motor or starting circuit; the ignition primary circuit; the ignition secondary circuit; the generator or charging circuit; and the light circuits.

For this study, if the laboratory does not furnish a chart of the car of the make desired, the student is to use the chart given in the Manual.

From the chart selected draw the following five distinct diagrams each showing one of the five different circuits. In these diagrams keep the same relative position of parts as in the given diagram. Some wires serve for two or more circuits. Label all parts.

I — Starting Circuit

Show connections of motor, starting switch, and battery.

II — Charging Circuit

Show connections of generator, ammeter, and battery.

III — Ignition Primary Circuit

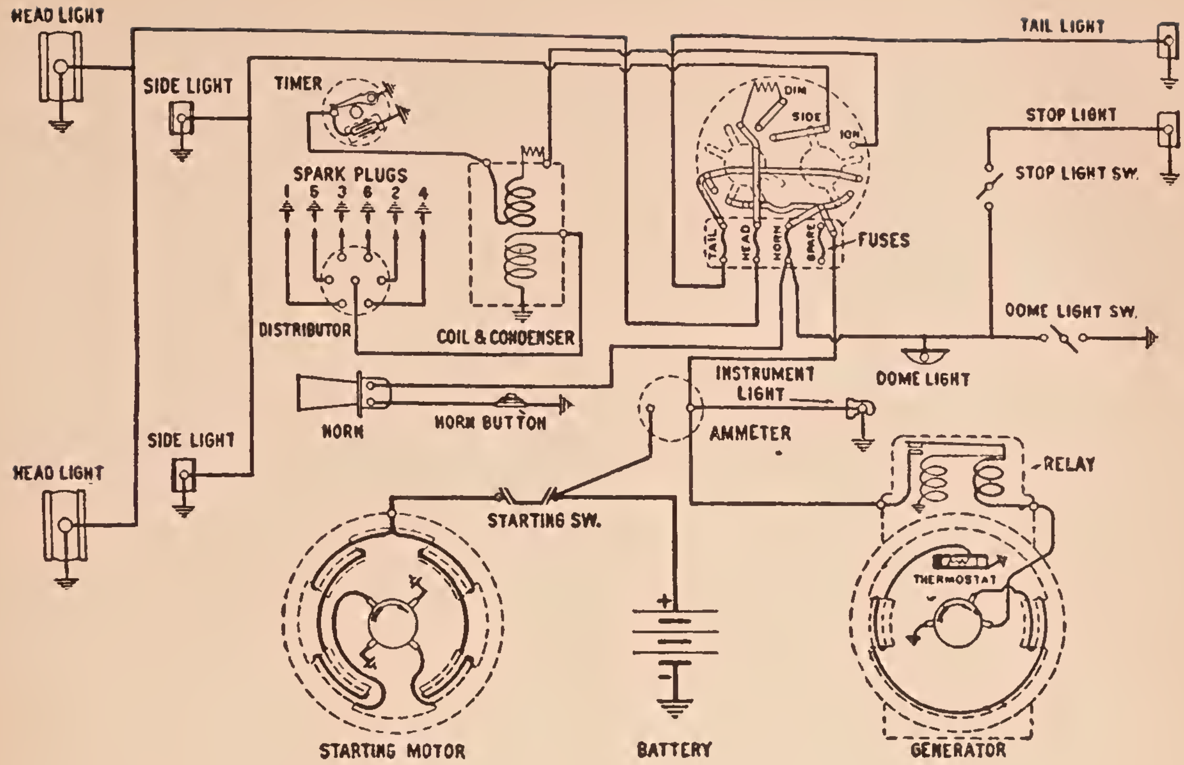
Show connections of battery, ammeter, ignition switch, primary coil, and timer.

IV — Ignition Secondary Circuit

Show connections of secondary coil, distributor, and spark plugs.

V — Light Circuits

Show connections of battery, ammeter, lighting switch, fuses, and lamps.



Optional

Explain the purpose of the following instruments in the system: Ignition coil; timer; relay; thermostat above generator.

PROJECTS

Project 1 — EFFICIENCY OF GAS WATER-HEATER

Study carefully the apparatus and note that the water may be passed through either heater at will by means of the stop-cock back of the heater.

To test the Sands heater open the stop-cock in water pipe back of the heater and close stop-cock back of the other heater. Next open the stop-cock near the water faucet at the sink. Adjust the faucet so that the rate of flow is a stream of water about the size of a lead pencil.

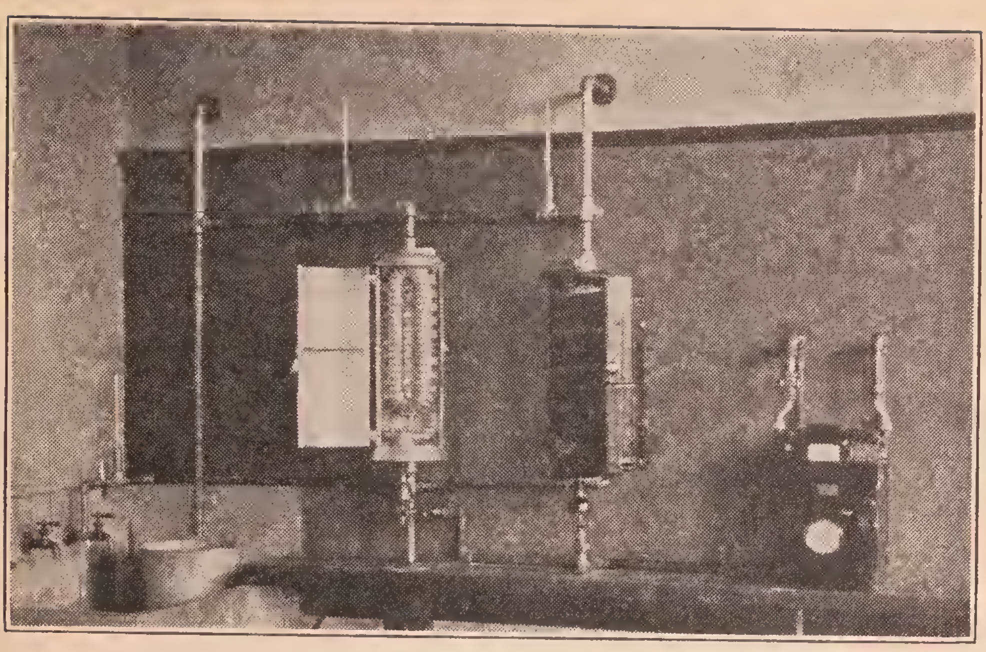
Light the gas in the Sands heater and open gas-cock fully. To avoid an explosion apply match and turn on gas at same time. Let the heater operate four or five minutes before starting the test. During this time open the cold-water tap and let water flow into the sink until thoroughly cold. Just before and immediately after the test the temperature of the water from the cold-water tap should be obtained. The average is to be taken as the temperature of the water before heating.

Determine the amount of water passing through while exactly two cubic feet of gas are burned.. One student will push the pail under the water exit pipe and remove it at the signals of a student observing the meter dials. Obtain the temperature of the heated water and weight.

From the weight of water in the pail and the change of temperature of the water passing through the heater, compute the number of B.T.U. received from the two cubic feet of gas. With the fuel value of gas as 560 B.T.U. per cubic foot, compute the input and efficiency of the heater. (See Note 2 below.)

Repeat the experiment in every detail using the Duplex. When comparing the efficiency of these two heaters, note that one is the coiled pipe type and the other the disc.

With gas at $.75 per 1000 cubic feet, compute the cost of heating 100 lb. of water from 72 to 212 degrees F. in each heater. Compute the cost of producing 1000 B.T.U. with each heater.



TABULATION

Make of Heater	Sands	Duplex
1st temperature cold water	....	....
2nd " " "	....	....
Temperature of water before heating	....	....
Temperature of hot water	....	....
Change in temperature	....	....
Weight of water	....	....
B.T.U. output	....	....
B.T.U. input	....	....
Efficiency	....	....
Cost of heating 100 lb.	....	....
Cost of 1000 B.T.U.	....	....

NOTE 1: If the hot-water heater at home is to be tested, first see that there is no hot water in the tank, then light the burner and open some nearby hot-water faucet so that a very small stream is flowing. Determine the temperature of the water from the hot-water faucet every few minutes and when the temperature becomes constant make the test by finding the weight and change of temperature of the water passing through the heater while two cubic feet of gas are burned.

NOTE 2: If the local fuel value and cost of gas are known, use them in place of the value and cost given in the experiment.

Project 2 — EFFICIENCY OF GAS STOVE

Weigh the kettle or vessel on the spring balance. Place in about two quarts (4 lb.) of water and weigh again.

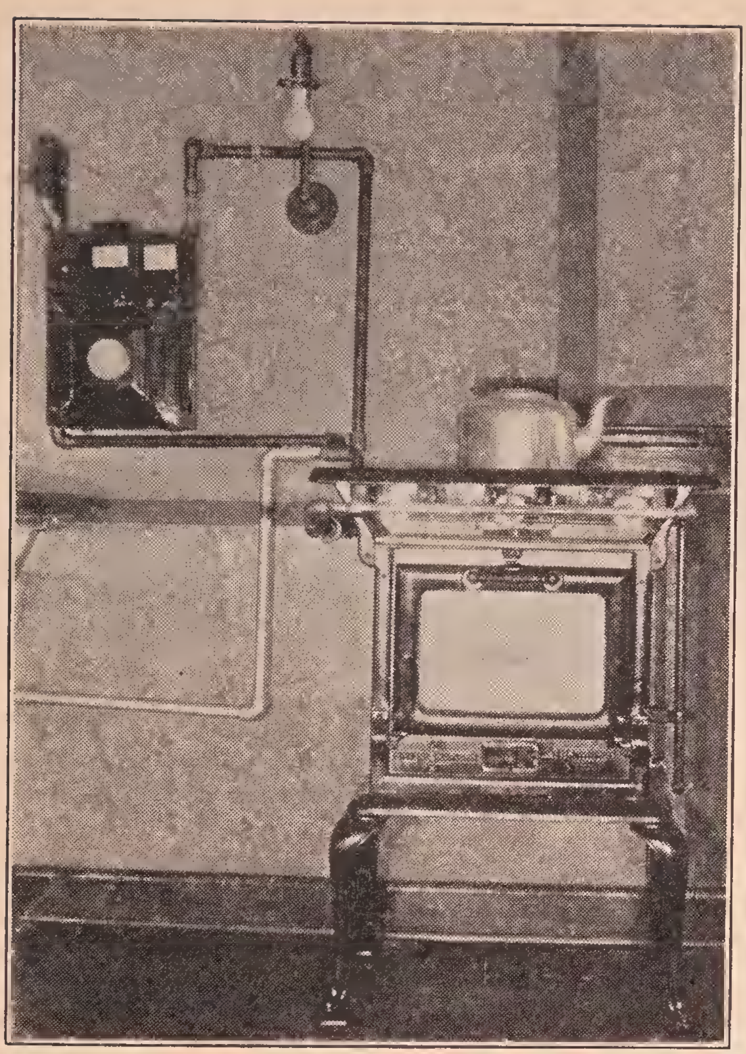
Light the gas burner to be tested and regulate the flow of gas so that the flame will be of medium size.

Take the temperature (F.) of the cold water and place the kettle on the flame. When exactly one cubic foot of gas has been burned to heat the water, remove the kettle and again take the temperature.

Calculate the number of B.T.U. received by the water. From the assumption that the heat of combustion of gas is 560 B.T.U. per cubic foot, determine the efficiency of the burner tested. In like manner determine the efficiency of the small jet or "simmer." (See Note 2 in Project 1.)

To test the oven, light the gas and regulate to a medium flame. Have the oven thoroughly heated before making the test. Use an open vessel and leave it in the oven while exactly two cubic feet of gas are burned. Make two tests by placing the vessel on the upper and lower shelves.

State your conclusions or comparisons. With gas at $.75 per 1000 cubic feet what is the cost per 1000 B.T.U. with the regular burner?



TABULATION

PART TESTED	REGULAR BURNER	SIMMER	UPPER OVEN	LOWER OVEN
Wt. of water	....	....	....	....
First temp.	....	....	....	....
Second temp.	....	....	....	....
Output (B.T.U.)	....	....	....	....
Gas used	....	....	....	....
Input (B.T.U.)	....	....	....	....
Efficiency	....	....	....	....
Cost of 1000 B.T.U.	....			

NOTE: This test may be made at home with the loan of a spring balance and a thermometer. Two students will need to work together; one to read the meter in the basement as the other works at the stove.

Project 3 — EFFICIENCY OF DIFFERENT KETTLES AND FLAMES

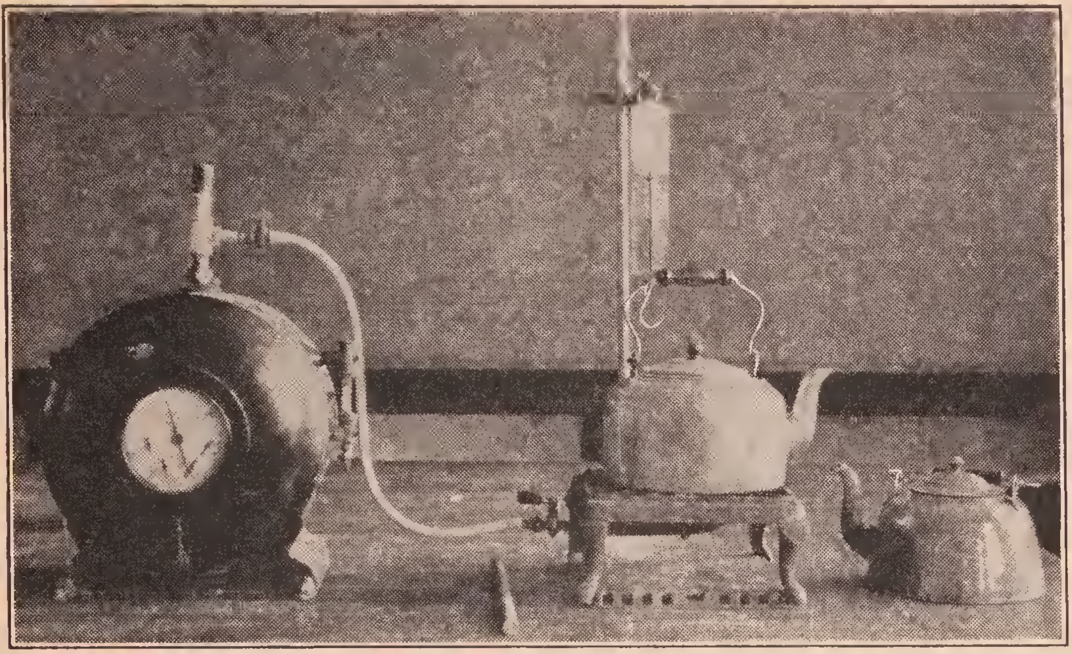
Weigh the kettle or vessel on the spring balance. Place in the vessel about two quarts (4 lb.) of cold water and weigh again. (Use a 30-lb. capacity balance.)

Light the burner and regulate to a maximum flame. Take the temperature (F.) of the cold water and place the kettle on the flame. When exactly one cubic foot of gas has burned to heat the water, take off the vessel and again take the temperature.

Calculate the number of B.T.U. received by the water. From the number of B.T.U. (560) supplied by the combustion of one cubic foot of gas, determine the efficiency of burner and kettle. (See Note 2 in Project 1.)

Make a similar test with the gas-cock half closed, to find the relative efficiency of high and low flames. Make such other tests as will enable you to compare the efficiency of covered and uncovered vessels and that of aluminum and granite vessels.

State your conclusion or comparisons. With gas at $.75 per 1000 cubic feet, compute the cost of a 1000 B.T.U. under the highest efficiency obtained.



TABULATION

MATERIAL	GRANITE	GRANITE	GRANITE	ALUMINUM
FLAME	HIGH	LOW	LOW	LOW
VESSEL	COVERED	COVERED	UNCOVERED	COVERED
Weight of water	....	....	....	....
First temperature	....	....	....	....
Second temperature	....	....	....	....
Output (B.T.U.)	....	....	....	....
Gas used (cu. ft.)	....	....	....	....
Input (B.T.U.)	....	....	....	....
Efficiency	....	....	....	....
Cost of 1000 B.T.U.			....	

NOTE: This test may be made at home with the loan of a spring balance and a thermometer. Two students will need to work together; one to read the meter in the basement as the other works at the stove.

Project 4 — PRESSURE COOKER

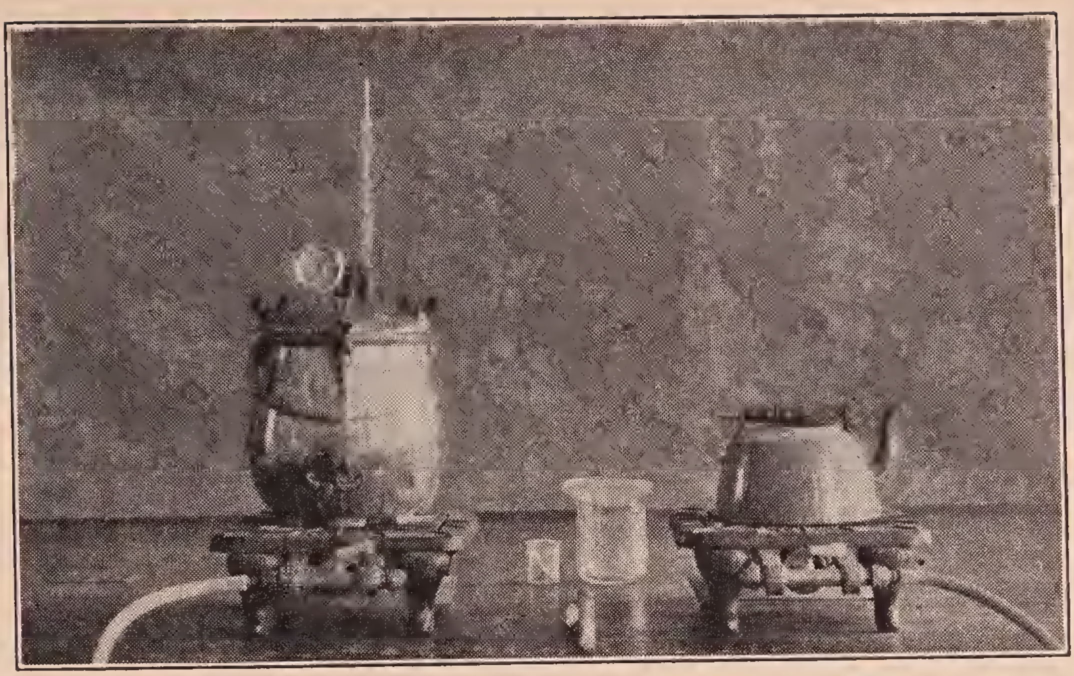
Part I — Effect of Pressure on Boiling Point

Place the cooker on the gas stove so that the ring and handle are directly in front. Put one quart of water in the cooker. Before putting on the cover, wipe dry its lower edge and the upper edge of the cooker. Place the cover on carefully and screw it down tight. Turn each wing nut a little at a time so that the pressure at the contact surfaces is increased uniformly at all points.

Light the gas and use full flame. The pet-cock on the cover should be closed. Watch the thermometer carefully and when it passes the ordinary boiling point (212° F. or 100° C.), open the pet-cock and let the steam and air escape. Regulate the gas so that the flame is about one-half of its former height.

When the pressure gauge reads zero, close the pet-cock. Now watch the gauge and the thermometer and record the temperature at each pound of increase in the pressure up to fifteen pounds. If necessary regulate the gas so that the increase takes place slowly. When through with the readings, turn off the gas and open the pet-cock. When cooled throw away the water and wipe dry the cover and vessel.

Calculate the average increase in temperature when the pressure is increased one pound per square inch. Calculate the temperature, F. and C., inside the boiler of a steam engine when the pressure gauge reads 200 pounds. Measure the diameter of the top of the cooker. Calculate the total pressure on the cover at the close of the test.



Part II — Effect of Pressure on Cooking

Bring from home two small potatoes of about the same size. Any other vegetables may be used if desired. If other vegetables are used, consult the instruction book for the proper time to cook with 20 pounds of pressure.

Place a quart of water in an open vessel on one burner. Place a pint of water in the cooker on another burner. Heat the water to the boiling point in both vessels. Note the time and place a potato in each vessel. Immediately place the cover on the cooker and screw it down tight.

Increase the flame so that the pressure will increase rapidly to 20 pounds. Now regulate the flame so that the pressure will remain constant at 20 pounds. (Be careful not to let the pressure get above 25. The safety valve should open at that pressure.)

When the potatoes have been cooking just ten minutes, turn off both flames and as soon as possible remove the potatoes from the vessels. Compare the condition of the potatoes and explain.

Weigh the vessel on a two-pan balance. Place an extra weight of one and one-half pounds on the weight pan. Pour water into the vessel until it is again perfectly balanced.

Set the stove at low heat and connect at the outer socket beneath the ammeter on the table switchboard. The ammeter is now in series with the stove. (See Note below.)

Place the vessel on the stove and take the temperature of the water. Cover the vessel and turn on the current by raising the lever on the side of the safety-switch box.

Record readings of the ammeter and voltmeter. To get the voltage, place the voltmeter plug in the other socket beneath the ammeter. When the vessel has been on exactly five minutes open the circuit and record the highest temperature of the water that can be obtained.

Calculate the number of B.T.U. received by the water. From the relation (1055 watt-seconds equal one B.T.U.) compute the heat developed in the stove during the heating of the vessel. Compute the efficiency of the stove.

Make a similar test to determine the efficiency of the stove when set at high heat. Obtain the local price of electrical energy per kilowatt-hour (lowest rate) and compute the cost of 1000 B.T.U. when set at high heat.

Note: Many cities require all electric circuits and connections, where the voltage is above 25, to be enclosed. The ammeter, voltmeter, and safety switch are consequently mounted on a box. One of the sockets underneath the ammeter is connected in series with the ammeter and switch. The other socket for voltmeter connection is connected parallel to the first.

If all electric connections are made by the student, call the instructor before closing the switch.

Tabulation

Stove Setting	Low Heat	High Heat
Weight of water	....	....
First temperature	....	....
Second temperature	....	....
Output (B.T.U.)	....	....
Amperage	....	....
Voltage	....	....
Time of current flow	....	....
Watt-seconds	....	....
Input (B.T.U.)	....	....
Efficiency of stove	....	....
Cost of 1000 B.T.U.		....

Weigh the vessel on a two-pan balance. Place an extra weight of one and one-half pounds on the weight pan. Pour water into the vessel until it is again balanced.

Set the stove at low heat and connect at the outer socket below the ten-ampere-range ammeter on the table switchboard. The ammeter is now in series with the electric stove. (See Note in Project 5.)

Place the vessel on the stove and take the temperature of the water. Cover the vessel and turn on the current by raising the lever on the side of the safety-switch box.

Record the reading of the ammeter and the voltmeter. To get the voltage of the circuit, place the terminal of the voltmeter cord in the other socket below the ammeter. When the vessel has been on exactly five minutes, open the circuit and record the highest temperature of the water that can be obtained.

Calculate the number of B.T.U. received by the water. From the relation (1055 watt-seconds produce one B.T.U.) compute the heat developed in the stove by the current in five minutes. Compute the efficiency of the stove.

Make a similar test to determine the efficiency of the stove when set at high heat. Obtain the local price of electrical energy per kilowatt-hour (lowest rate) and compute the cost of 1000 B.T.U. when set at high heat.

TABULATION

STOVE SETTING	LOW HEAT	HIGH HEAT
Weight of water	....	....
Temperature of cold water	....	....
Temperature after heating	....	....
Temperature change	....	....
Output (B.T.U.)	....	....
Amperage	....	....
Voltage	....	....
Time of current flow	....	....
Watt-seconds	....	....
Input (B.T.U.)	....	....
Efficiency of stove	....	....
Cost of 1000 B.T.U.		....

Project 7 — EFFICIENCY OF ELECTRIC WATER-HEATER

Weigh the electric water-heater without the cover on a two-pan balance. Place on the weight pan an extra weight of one and one-half pounds and pour water into the heater until it is again perfectly balanced.

Connect the heater at the outer socket underneath the five-ampere-range ammeter on the table switchboard. The ammeter is now in series with the heater. (See Note in Project 5.)

Take the temperature (F.), place on the cover and close the circuit for exactly three minutes. (To close the circuit raise the lever on the side of the safety switch.)

During the three minutes record the amperage and the voltage. To get the voltage, place the terminals of the voltmeter cord in the other socket below the ammeter.

About one minute after opening the circuit take the temperature of the water. Watch the thermometer for some time and record the highest temperature obtained.

Calculate the number of B.T.U. received by the water. From the relation (1055 watt-seconds are equivalent to one B.T.U.), compute the heat developed in the heater. Determine the efficiency of the heater.

Make a second test with the cover off. Before making the second test, thoroughly cool the heater by letting cold water from the tap run into it.

Obtain the local price of electrical energy per kilowatt-hour (lowest rate) and compute the cost of 1000 B.T.U. in the test of highest efficiency.

TABULATION

Condition of Vessel	Cover On	Cover Off
Weight of vessel	....	....
Weight of vessel and water	....	....
Weight of water	....	....
Temperature of cold water	....	....
Temperature after heating	....	....
Temperature change	....	....
Amperage	....	....
Voltage	....	....
Time of current flow	....	....
Watt-seconds	....	....
Input (B.T.U.)	....	....
Output (B.T.U.)	....	....
Efficiency of heater	....	....
Cost of 1000 B.T.U.	....	

Project 8 — EFFICIENCY OF ELECTRIC FIRELESS COOKER

Weigh the inner vessel of the cooker on the spring balance. Put in about three quarts of cold water and weigh again. (Use the 30-lb. capacity balance.)

Connect the cooker at the outer socket beneath the ten-ampere-range ammeter on the table switchboard. The ammeter is now in series with the cooker. When determining the voltage, place the voltmeter plug in the other socket beneath the ammeter. The voltmeter is now connected across the wires leading to the cooker. (See Note in Project 5.)

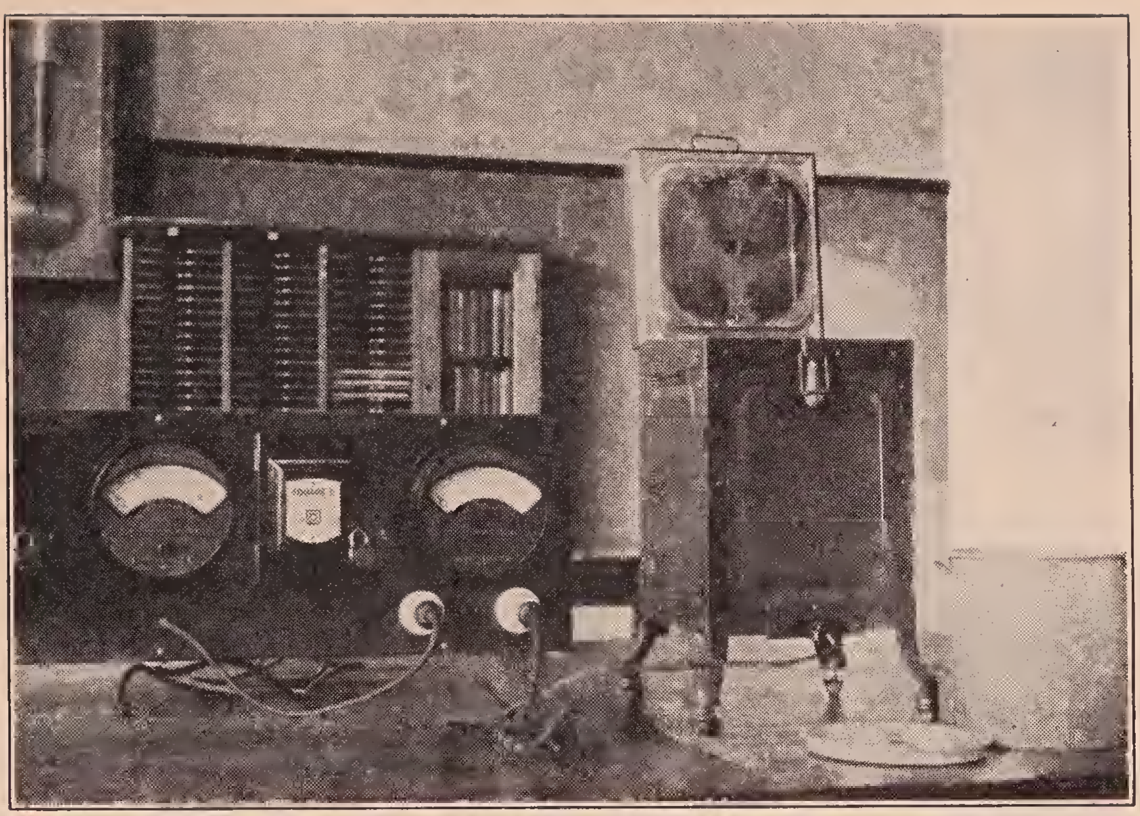
Record the temperature of the cold water. Seal the vessel and place it in the cooker. Close the safety switch and pass current through the cooker exactly ten minutes.

The ammeter and the voltmeter should be read at the beginning and near the end of the ten minutes. If readings vary take average.

Twenty minutes after the current is turned off, open the cooker and carefully take the temperature of the water. During the twenty minutes make a diagram showing connections of cooker, ammeter, voltmeter, and switch.

Compute the number of B.T.U. received by the water. From the relation (1055 watt-seconds are equivalent to one B.T.U.), compute the heat developed in the cooker during the ten minutes of current flow. Determine the efficiency of the cooker.

Obtain the local price of electrical energy per kilowatt-hour (lowest rate) and compute the cost of 1000 B.T.U.



TABULATION

Weight of inner vessel	....
Weight of vessel and water	....
Weight of water	....
Temperature of cold water	....
Temperature after heating	....
Temperature change	....
Amperage	....
Voltage	....
Time of current flow	....
Watt-seconds	....
Input (B.T.U.)	....
Output (B.T.U.)	....
Efficiency of cooker	....
Cost of 1000 B.T.U.	....

Project 9 — ELECTRIC LIGHTS — COST PER C.P. HOUR

Place the standard incandescent light at one end of the optical bench. Place the lamp to be tested at a distance 100 centimeters from the standard. Slide the photometer back and forth between the lights until a position is found where the screen is equally illuminated on both sides.

As it is difficult to set the photometer at its correct position, several trials should be made and the average recorded. One method is to place the photometer too far to the right and move it to the left until the oiled spot is apparently equally illuminated on each side. Find a second point by approaching from the left. A point midway between these two points is to be recorded as the correct position of the photometer.

Measure the distance from the screen of the photometer to the center of the standard and from the screen to the center of the lamp tested. Compute the candle power of the lamp.

Test such lamps that will enable you to compare the relative cost per candle-power-hour of low and high wattage lamps; of frosted and clear lamps; of fresh and used lamps; of Mazda B and Mazda C lamps.

To determine the exact wattage of the lamp tested use a one-ampere meter of the table switchboard. To get the voltage place the terminals of the voltmeter cord in the other socket below the ammeter. When reading the ammeter disconnect the voltmeter. (See Note in Project 5.)

From the wattage and the candle power compute the watts per candle power. With electrical energy at ten cents per kilowatt-hour, compute the cost of using each lamp for one hour. From this cost and the candle power of the light, compute the cost per candle-power-hour for each lamp. State conclusions.

TABULATION

LAMP TESTED	....	....	....	....	....
Distance (phot. to lamp)	....	....	....	....	....
Distance (phot. to stand.)	....	....	....	....	....
Candle power of lamp	....	....	....	....	....
Amperage	....	....	....	....	....
Voltage	....	....	....	....	....
Wattage (computed)	....	....	....	....	....
Watts per candle power	....	....	....	....	....
Cost of lamp per hour	....	....	....	....	....
Cost per C.P. Hour	....	....	....	....	....

Project 10 — HOUSEHOLD LAMP CONNECTIONS

In some cities it is required that all electric connection and circuits be enclosed, if the voltage is above 25. The box shown in the picture is a suggestion of how to meet those requirements and still give the student the experience of making and testing the different kinds of connections.

The door of the box cannot be opened without disconnecting it from the switchboard. When the lamp receptacles have been connected as desired and the connection approved by the instructor, then close the door and connect the circuit to the switchboard. The lamps must be placed in the receptacles after the door is closed.

If enclosed circuits are not required and all connections are made by the student, connect first the receptacles as desired and then connect in series with the ammeter. The voltmeter should be connected to the two points whose difference of pressure is to be measured.

Part I — Parallel Connections

Connect one lamp in series with the ammeter. Connect the voltmeter across the terminals of the source of the current. The voltmeter should be disconnected when reading the ammeter. Connect two lamps in parallel and again read the ammeter and the voltmeter.

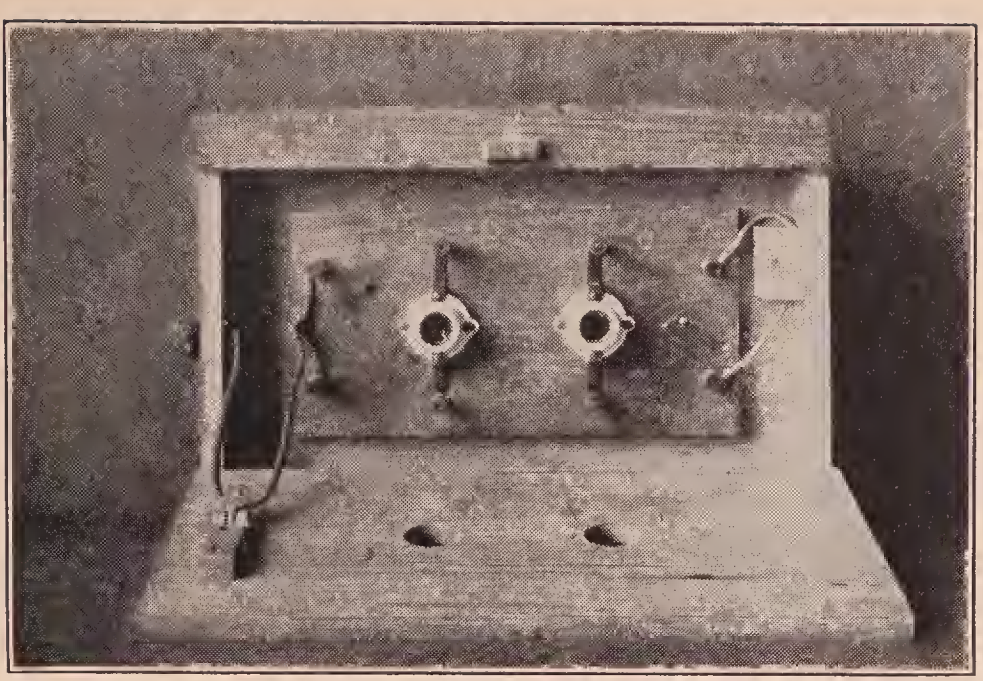
If a residence had twenty such lamps connected in parallel, compute the amperage and the voltage if all lamps were in service. At ten cents per kilowatt-hour, compute the cost of running all lamps one hour.

Part II — Series Connections

Connect two lamps in series and determine the amperage. Determine as before the voltage of the source and also the voltage across the terminals of one lamp. Note the intensity of the light.

Compute the voltage necessary at the source to cause the two lamps to give their normal amount of light. Compute also what the ammeter would then read.

If a residence had twenty such lamps connected in series, compute the amperage and the voltage if all lamps were in service. At ten cents per kilowatt-hour, compute the cost of running all lamps one hour.



Tabulation

Part I — Parallel Connections

Amperage of one lamp	....
Voltage for one lamp	....
Amperage of two lamps	....
Voltage for two lamps	....
Amperage of twenty lamps	....
Voltage for twenty lamps	....
Cost of twenty lamps for one hour	....

Part II — Series Connections

Amperage obtained with two lamps	....
Amperage necessary for two lamps	....
Amperage for twenty lamps	....
Voltage of source	....
Voltage of one lamp	....
Voltage necessary for two lamps	....
Voltage for twenty lamps	....
Cost of twenty lamps for one hour	....

Project 11 — HEAT AND LIGHT RADIATIONS OF LAMPS

Weigh the calorimeter on a platform balance to the nearest tenth of a gram. Weigh the vessel about one-half full of water, six or eight C. degrees below room temperature.

By means of a universal clamp support an electric-light socket in a vertical position so that the lamp can be raised or lowered on the support rod. Place in the socket a 60-watt lamp.

Connect the lamp to the outer socket beneath the one-ampere ammeter on the switchboard. The lamp is now in series with the ammeter. To determine the voltage, place the plug connected to the voltmeter in the other socket below the ammeter. (See Note in Project 5.)

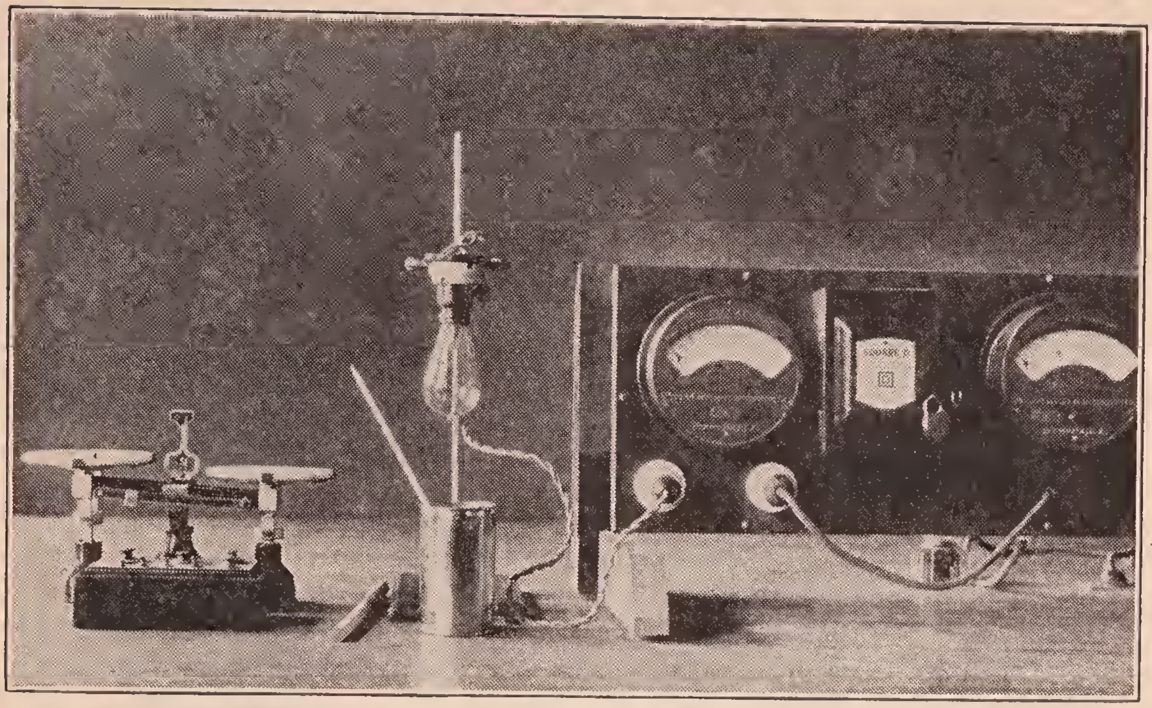
Lower the lamp into the calorimeter until the brass base is just above the surface of the water. Take the temperature (C.) of the water and immediately turn on the current. Record the amperage and voltage. At the close of exactly five minutes turn off the current. Stir the water with the thermometer and record the highest temperature obtained.

Compute the number of calories received by the water and by the vessel. (Sp. heat of the vessel, 0.1.)

Repeat the experiment, using the glass beaker in place of the calorimeter. (Sp. heat of glass, 0.2.)

From the amperage, voltage, and time compute the number of watt-seconds or joules. From the heat equivalent of an electric current (one joule is equal to 0.24 calorie), compute the number of calories generated by the current in five minutes.

An electric light radiates both heat and light energy. With the metal vessel both heat and light energies are converted into heat. With a glass vessel the light energy passes through and only the heat energy is absorbed by the water and the vessel. Thus the difference in the number of calories received, when using glass and metal vessels, is a measure of the light energy that is transformed into heat or the output of the lamp in light energy. Compare this with the total input or the calories generated by the current, and compute the percentage of the electrical energy of the current a lamp converts into light.



TABULATION

Vessel Used	Calorimeter	Glass Beaker
Weight of vessel	....	....
Weight of vessel and water	....	....
Weight of water	....	....
Temperature of cold water	....	....
Temperature after heating	....	....
Calories received by water	....	....
Calories received by vessel	....	....
Calories received, total	....	....
Amperage of lamp	....	
Voltage of lamp	....	
Time of current flow (seconds)	....	
Watt-seconds, joules	....	
Calories generated by current	....	
Calories (heat and light energy)	....	
Calories (light energy)	....	
Percentage of light energy	....	

Remove the top from the gas flatiron. Turn on the gas and immediately light it in the iron. Adjust the gas supply until the gauge reads about six cubic feet per hour.

If not familiar with the usual method of determining the proper temperature for ironing, give the iron five or six minutes to heat before beginning to iron.

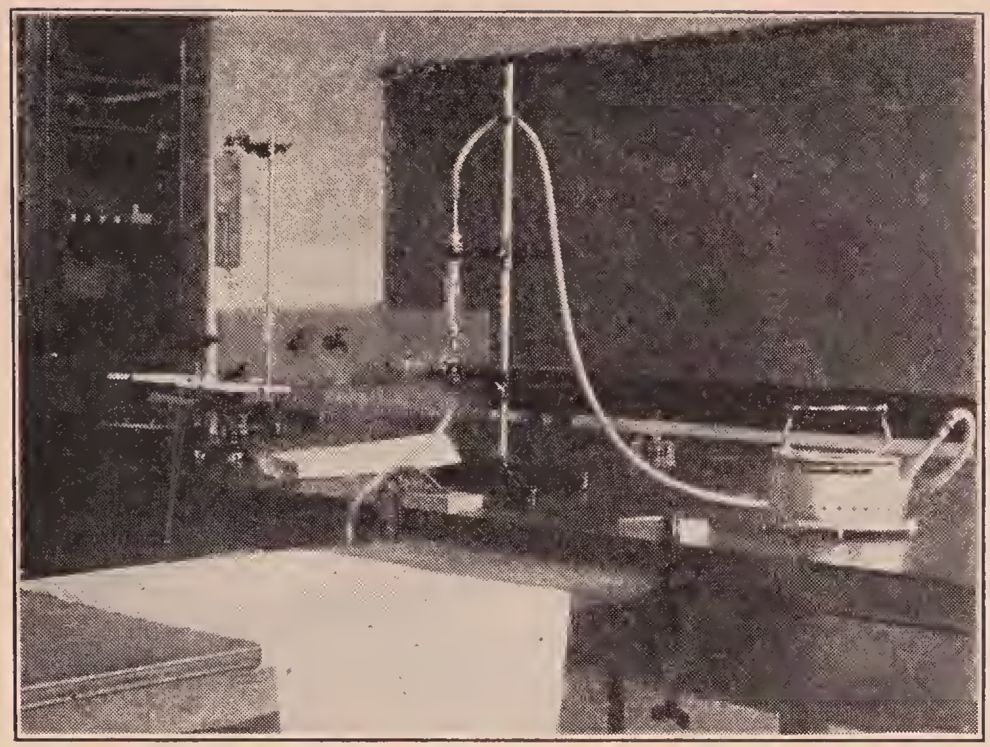
During the time that the iron is heating, thoroughly soak the towel and then wring as dry as possible. Weigh on the platform balance to the nearest tenth of a gram.

While one student is ironing the other should determine by means of a stop-watch the exact time that the iron is in contact with the towel. The watch is operated by moving the side piece. It records the time for the performance, excluding interruptions. If the iron is lifted from the towel the watch should be stopped until the ironing is continued.

Iron rapidly so as to waste as little heat as possible until the towel is entirely dry. Turn off the gas immediately at the close of the test. Weigh the ironed towel to the tenth of a gram.

Compute the efficiency of the iron. To determine the output of the iron in calories, compute the heat necessary to change the water of the towel (loss in weight) from room temperature to boiling point (C.) and to change it into vapor. To find the input or heating power of the gas used during the test, consider the heat of combustion of gas as 141,400 calories per cubic foot.

Each student should iron a towel for the data of his own individual record. Obtain the local price of gas per 1000 cubic feet and compute the cost of ironing the towel.



Tabulation

Weight of damp towel	....
Weight of ironed towel	....
Weight of water evaporated	....
Room temperature (C.)	....
Calories — to raise temperature	....
Calories — to evaporate	....
Output — calories	....
Gauge reading (cu. ft. per hr.)	....
Time of ironing	....
Cubic feet of gas used	....
Input — calories	....
Efficiency of iron	....
Cost of ironing the towel	....

Connect the iron to the outer socket below the five-ampere-range ammeter on the table switchboard. To determine the voltage connect the terminal of the voltmeter cord to the other socket below the ammeter. (See Note in Project 5.)

If not familiar with the usual method of determining when the iron is at the proper temperature for ironing, give the iron five or six minutes to heat before starting to iron.

During the time that the iron is heating, thoroughly soak the towel and wring as dry as possible. Weigh the towel on the platform balance to the nearest tenth of a gram.

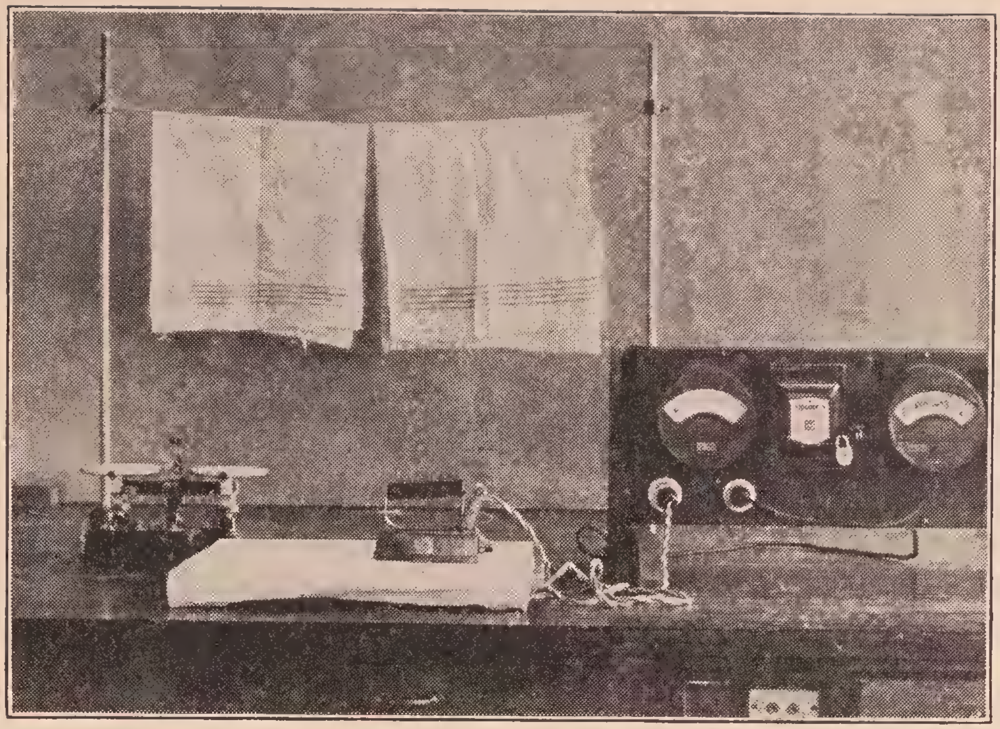
While one student is ironing the other should determine by means of a stop-watch the exact time that the iron is in contact with the towel.

The watch is operated by moving a side piece. It records the total time used for the performance, excluding interruptions. If the iron is lifted from the towel, the watch should be stopped until the ironing is continued.

Iron rapidly so as to waste as little heat as possible until the towel is thoroughly dry. Open the safety switch immediately at the close of the test. Weigh the ironed towel to the tenth of a gram.

Compute the efficiency of the iron. To determine the output of the iron in calories, compute the heat necessary to change the water of the towel (loss in weight) from the room temperature (C.) to the boiling point and to evaporate the water. To find the input or heating power of the current for the time used, apply the formula (one calorie equals 4.17 watt-seconds).

Each student should iron a towel for the data of his own record. Obtain the local price of electrical energy per kilowatt-hour (lowest rate) and compute the cost of ironing the towel.



TABULATION

Weight of damp towel	....
Weight of ironed towel	....
Weight of water evaporated	....
Room temperature (C.)	....
Calories to raise temperature	....
Calories to evaporate	....
Output (calories)	....
Reading of ammeter	....
Reading of voltmeter	....
Time of ironing	....
Watt-seconds	....
Input (calories)	....
Efficiency of iron	....
Cost of ironing towel	....

Project 14 — HORSEPOWER AND EFFICIENCY OF ELECTRIC MOTOR

In an alternating-current circuit containing coils the true power is obtained by multiplying the apparent power (product of volts times amperes) by some number, called the power factor, which can be obtained from the manufacturer. The power factor of the one-fourth horsepower Western Electric induction-repulsion motor, type RSA, is 0.60.

To determine the horsepower of the motor use the device known as the Prony brake. As the shaft rotates the difference between the two balances will give the pounds of pull on the face of the pulley. This force or pull will be exerted each minute through a distance equal to the circumference of the pulley times the number of revolutions per minute. From the force and the distance, the work done per minute and the horsepower can be computed.

Connect the motor to the outlet below the ten-ampere-range ammeter on the switchboard. Place the terminal of the voltmeter cord in the other outlet below the ammeter. The ammeter is now connected in series and the voltmeter in parallel with the motor. Start the motor by raising the lever on the side of the safety-switch box. (See Note in Project 5.)

While the motor is running, place the belt about the pulley and raise the balances until the difference of readings is about nine pounds (full load).

One student should determine by means of the speed indicator the number of revolutions made per minute. At the same time the second student should read and record the amperage and voltage. Watch the meters and balances and, if they vary during the test, take the average reading.

Immediately at the end of the minute stop the motor. The motor should not be left running under load any longer than is necessary, as the friction will soon destroy the belt and the motor may be injured by overheating.

Measure the circumference of the pulley by means of a rope of the same size as the rope used for the belt.

Compute the work done per minute and the horsepower (output) of the motor. From the amperage, voltage and power factor, compute the input in watts and in horsepower. Determine the efficiency of the motor.

Make a second test with a smaller load, with a difference of balance readings of about six pounds.

TABULATION

LOAD DURING TEST	FULL LOAD	PART LOAD
Voltmeter reading	....	....
Ammeter reading	....	....
Power factor of motor	....	....
Input in watts	....	....
Input in horsepower	....	....
Balance reading No. 1	....	....
Balance reading No. 2	....	....
Force on belt (pounds)	....	....
Circumference of pulley	....	....
No. of revolutions per minute	....	....
Distance in feet per minute	....	....
Foot pounds per minute	....	....
Output in horsepower	....	....
Efficiency of motor	....	....

Project 15 — HORSEPOWER AND EFFICIENCY OF WATER MOTOR

To start the motor care must be taken to turn on the water *very slowly*. When shutting off the water to stop the motor the same care must be taken to do it slowly.

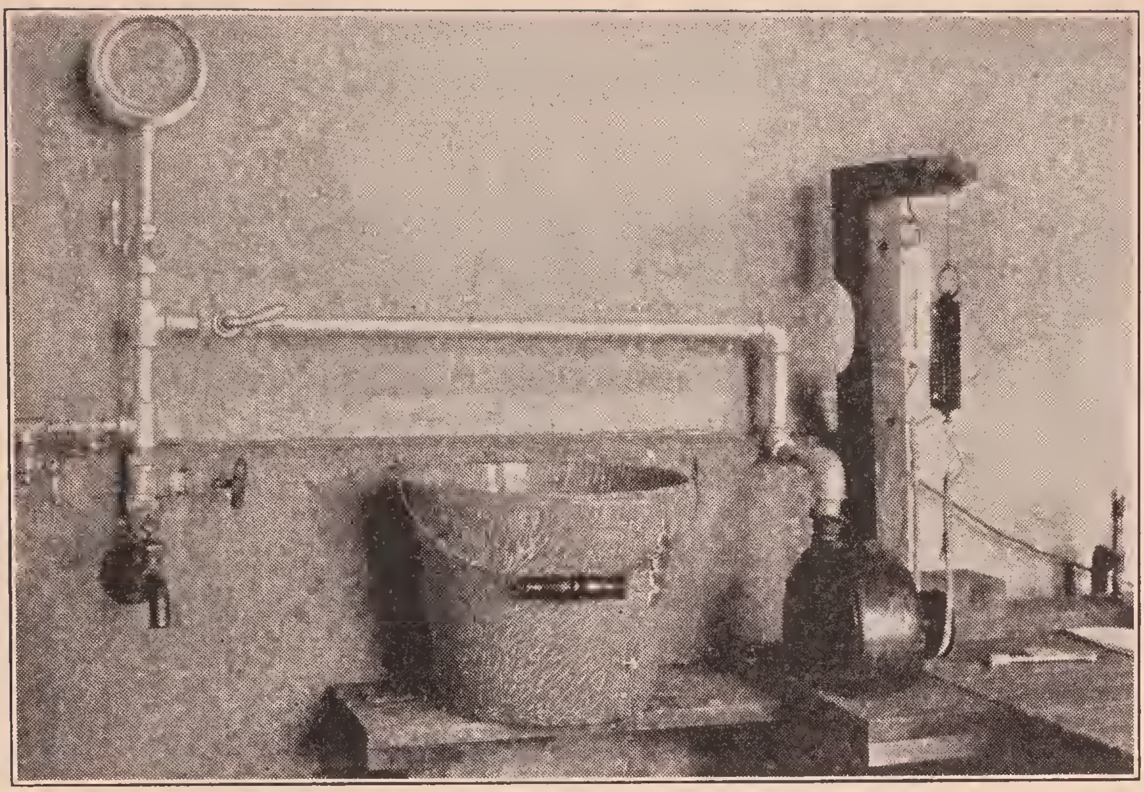
To determine the horsepower of the motor use the device known as the Prony brake. As the shaft rotates the difference between the two balances will give the pounds of pull on the face of the pulley. This force or pull will be exerted each minute through a distance equal to the circumference of the pulley times the revolutions per minute. The work done in one minute will be this pull times the distance per minute, from which the horsepower can be computed.

When the motor has reached full speed, gradually raise the spring balances until the load or pull on the belt is as great as the motor can work. One student should determine by means of a speed indicator the number of revolutions made in one minute. During this time the second student should place a vessel under the outlet and catch the flow for one-half of a minute and record the reading of the pressure gauge.

Determine the circumference of the pulley by means of a rope of the same size as that used for the belt. From the circumference, the number of revolutions and the brake pull, compute the work done per minute and the horsepower of the motor.

The input or work done on the motor is called fluid work and is equal to the pressure or force times the distance the water flows per minute. Since the gauge gives the pressure per square inch, the size of the pipe may be considered as one square inch in cross-section. The volume in cubic inches flowing per minute will then give the distance in inches that the water flows per minute.

Weigh the water that passed through the motor during the half minute of test and compute its volume in cubic inches. Express the distance the water flows per minute in feet and compute the input or work done on the motor. Compare with the output or work done by the motor on the brake and determine the efficiency of the motor.



TABULATION

First balance reading	.... oz.
Second balance reading	.... oz.
Output force (dif. of readings)	.... lb.
Circumference of pulley	.... in.
Number of revolutions per minute	....
Output distance	.... ft.
Output (foot pounds per minute)	....
Horsepower of motor	....
Input force (water pressure per sq. in.)	.... lb.
Weight of water per minute	.... lb.
Volume of water per minute	.... cu. in.
Input distance (velocity of water)	.... ft.
Input (foot pounds per minute)	....
Efficiency of water motor	....

Project 16 — HORSEPOWER AND EFFICIENCY OF GAS ENGINE

Study carefully the directions and have thoroughly in mind all that is to be done before starting the experiment.

The efficiency of an engine is the ratio of the work developed at the crankshaft to the work or energy supplied to the engine in the fuel. The heat value of the gas here used is to be taken as 560 B.T.U. per cubic foot. Knowing the gas consumed per minute and the mechanical equivalent of heat, the input can be computed.

To determine the brake horsepower use the device known as the Prony brake. As the shaft rotates the difference between the two balances will give the pounds of pull on the face of the pulley. This force or pull will be exerted each minute through a distance equal to the circumference of the pulley times the revolutions per minute. The work done in one minute will then be this pull times the distance per minute, from which the horsepower can be computed.

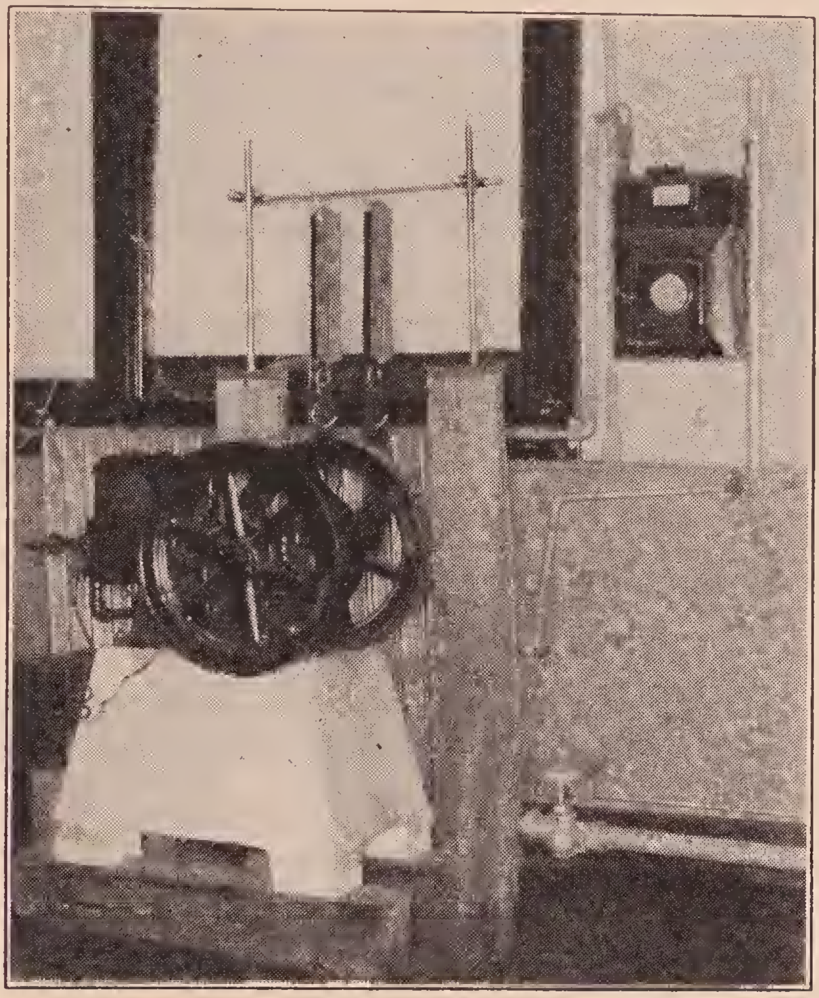
When ready to start the engine, call the instructor. Have the water jacket filled within an inch or two of the top; open full the gas-cock beneath the gas meter; close the electric switch on the side of the battery box.

To crank the engine turn the wheel back as far as you can without effort and then with a quick movement clockwise turn it through one compression and immediately let loose the handle. If it does not start, repeat; but *under no consideration keep hold of the handle for more than one revolution.*

When the engine is running smoothly raise the spring balances until the difference of the readings is about 25 pounds. One student should determine by means of the speed indicator the number of revolutions made in one minute. At the same time the second student should observe the one-half cubic foot dial of the gas meter and determine the volume of gas used per minute. Record the readings of the two spring balances and stop the engine by opening the electric switch. Close the gas-cock. The engine should not be left running under load any longer than necessary, as the friction would soon destroy the belt.

Measure the diameter or circumference of the pulley wheel and compute the work done per minute or the brake horsepower. From the volume of gas consumed compute the

energy given to the engine per minute. Determine the efficiency of the engine. Make a second test with a smaller load, with a difference of balance readings of about 15 pounds.



TABULATION

Load during Test	Full Load	Part Load
Circumference of pulley	....	....
First balance reading	....	....
Second balance reading	....	....
Force (pull of belt)	....	....
Revolutions per min.	....	....
Distance (ft. per min.)	....	....
Work per min. (ft. lb.)	....	....
Horsepower of engine	....	....
Gas used (cu. ft.)	....	....
Heat equivalent of gas used	....	....
Mech. equivalent of gas used	....	....
Efficiency of gas engine	....	....

Remove the cylinder-head casting from the engine. (When a mechanism is to be taken apart, carefully observe the arrangement and parts as they are removed so that they may be properly reassembled at close of study.)

1. Record the make of car and the number of cylinders. Measure and record the bore and stroke.

2. Compute the displacement of the engine. The displacement of one cylinder is the cross-section area times the stroke.

3. Record the type of valve: Sleeve or poppet.

4. If poppet, classify the engine according to the location of valves.

5. Determine which is the intake valve and which is the exhaust by the difference in the cams.

6. Record the number of main bearings on the crankshaft. Is the crankshaft equipped in any way to reduce vibrations?

7. Determine the type of front end drive — or how the camshaft is driven by the crankshaft. By chain or by gears? If gears, spur or helical?

8. Record the make of carburetor and determine, if possible, the method of preventing rich mixture as speed is increased.

9. Has the carburetor a choke or primer for making mixture richer when starting?

10. Is the carburetor equipped with any air-heating device?

11. Is the intake manifold equipped with hot-spot, hot-water jacket, or exhaust-gases jacket?

12. Determine if the exhaust manifold is single or double and if equipped with a cut-out.

13. Classify the cooling system: Air or water; thermosyphon or pump. If the pump system, is there a thermostat control?

14. Classify the oiling system: Splash; pressure; pressure-splash.

15. Explain how the following parts are lubricated: Cylinder walls; camshaft bearings; crankshaft bearings; connecting rod bearings.

NOTE: If the laboratory is not provided with an automobile engine, most of the above questions may be answered for the home car by a study of the engine and the Book of Instructions furnished with the car.

Project 18 — STUDY OF AUTOMOBILE CHASSIS

1. Determine and record the make and model of the laboratory chassis or the car to be studied.

2. Measure the wheel base on each side of the car by measuring the distance from center of rear axle to center of front axle.

3. Set the front wheels for a straight, forward movement and check the alignment:

(*a*) Camber. Measure the distance between the two front-wheel rims at the top and at the bottom. Record difference as the camber.

(*b*) Toe-in. Measure the distance from rim to rim at the front and at the rear of the front wheels at the level of the hub. The difference is the toe-in.

4. Classify the clutch: (*a*) Cone or disc; (*b*) Single disc (plate) or multiple; (*c*) Run dry or in oil.

5. From a study of the gear set determine the type of shift: Universal or standard. Record number of speeds forward.

6. Observe the number and location of the universals. Classify as fabric or metal.

7. Is the propeller shaft hollow or solid? Is it exposed or enclosed in a tube (torque tube)?

8. Determine the type of rear axle: Semi-floating; if the weight of the car rests on the axle or if the bearings are between axle and housing. Floating; if the axle is not under the strain of the weight of the car or if the bearings are between housing and hub of wheel.

9. Determine the type of rear axle bearings: Ball; roller; tapered cone (Timken).

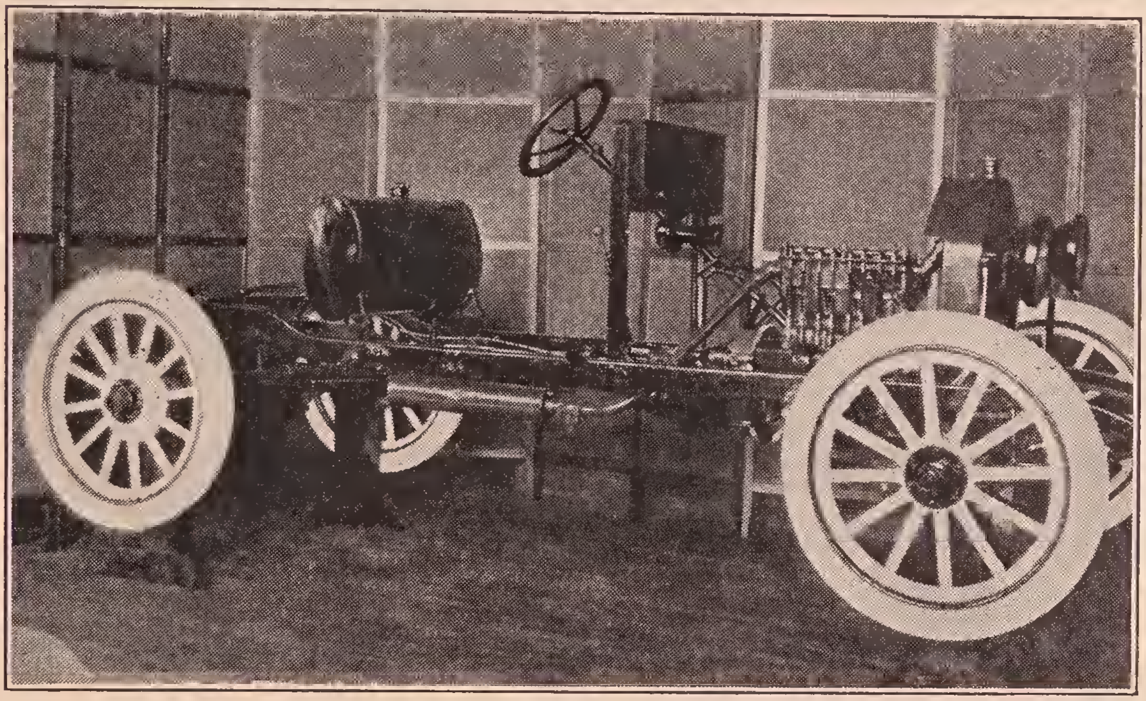
10. Determine the type of rear drive: Spring; if the push of the rear wheels against the frame of the car is through the springs. Torque tube; if the tube is fastened rigidly to the frame. Hotchkiss; if there are two universals.

11. State the number and type of brakes; the location (internal or external) of the hand and of the foot brakes.

12. Classify the rear springs: Semi-elliptic; three-quarter elliptic; full elliptic; cantilever; platform.

13. Give location of tank and state method of getting the gasoline from tank to carburetor (feed system): Gravity; pressure; vacuum tank.

14. Determine the type of motor drive or the method of connecting the starting motor to the crankshaft when starting: Bendix drive; pedal mechanism; chain connection.



NOTE: If the laboratory is not equipped with an automobile chassis, make a study of the home car. If questions cannot be answered by observation, consult the Book of Instructions supplied with the car.

By gear ratio of an automobile is meant the number of revolutions of the crankshaft of the engine to one revolution of the rear-axle shafts.

If the transmission gears are placed in "high" or direct drive, the crankshaft of the engine is connected directly to the propeller shaft and the only reduction in the number of revolutions will be in the differential.

Count the number of teeth in the ring gear and in the drive pinion gear of the differential and determine the number of times the crankshaft revolves to one revolution of the rear-axle shafts.

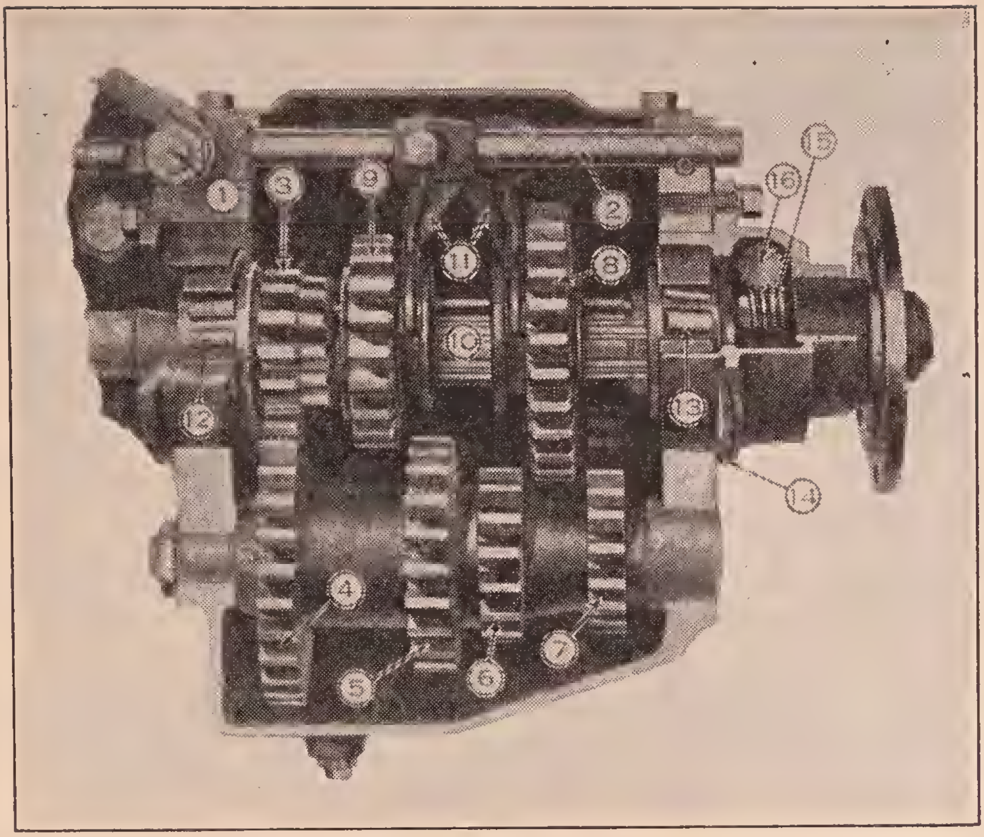
To determine the gear ratio when in "second," place the shift lever in intermediate or second and then remove the top of the gear-set box. Count the number of teeth in the clutch-shaft gear and in the constant mesh gear and determine the ratio of rotations of clutchshaft to countershaft.

Count the number of teeth in the countershaft second or intermediate gear and in the intermediate shifter gear on the driveshaft. Determine the ratio of rotations of the countershaft to the driveshaft.

From these two ratios and the ratio of ring gear to drive-pinion gear in the differential compute the number of revolutions of the crankshaft to one revolution of the rear-axle shafts or the gear ratio when in "second."

Count the number of teeth in the countershaft low gear and in the shifter low gear on the driveshaft. Compute as before the number of revolutions of the crankshaft to one revolution of the rear-axle shafts or the gear ratio when in "low."

NOTE: If the gear ratios of the home car are to be determined, jack up one of the rear wheels and set the shift lever in the gear or speed to be tested. Count the number of revolutions of the starter crank necessary to rotate the rear wheel through one revolution. Multiply this number by two, as only one wheel is rotating.



1 — Shifter Lock Adjustment
2 — Shifter Bar
3 — Clutchshaft Gear
4 — Constant Mesh Gear
5 — Second Speed Gear
6 — First Speed Gear
7 — Reverse Speed Gear
8 — First and Reverse Shifter Gear
9 — Second and High Shifter Gear
10 — Transmission Shaft
11 — Shifter Fork
12 — Clutchshaft Bearing
13 — Transmission Shaft Bearing
14 — Adjusting Shims
15 — Speedometer Drive Gear
16 — Speedometer Drive Gear

TABULATION

Number of teeth in ring gear	....
Number of teeth in drive pinion	....
Gear ratio in high	....
No. of teeth in clutchshaft gear	....
No. of teeth in countershaft gear	....
Ratio — clutchshaft to countershaft	....
No. of teeth in countershaft second gear	....
No. of teeth in driveshaft second gear	....
Ratio — countershaft to driveshaft	....
Gear ratio in second	....
No. of teeth in countershaft low gear	....
No. of teeth in driveshaft low gear	....
Ratio — countershaft to driveshaft	....
Gear ratio in low	....

1. Determine if the car is equipped with a single or two-unit electric system. If the starting motor and generator are separate instruments, it is two-unit. A single instrument may serve both purposes and is called a starter-generator.

2. Classify the ignition system as battery or magneto. Determine by the source of the current used for ignition.

3. Raise the cap from the distributor and determine the direction of rotation of the arm. From the rotation and the connections to the spark plugs, determine the firing order. Cylinder nearest to the radiator is No. 1.

4. Move the spark lever or control and discover its action on the distributor. Explain how it changes the time of the spark.

5. Discover, if possible, the position of the "cut-out" or device for connecting or disconnecting generator at different speeds.

6. Discover, if possible, if there is a "third brush" on the generator or a thermostat in its circuit. These are devices (regulators) for preventing the generator from producing excessive current at high speeds.

7. Determine the method of dimming the headlights. The more common methods are: Place extra resistance in the circuit; change the connection of the lamps from parallel to series; place auxiliary bulbs in the head lamps.

8. Draw a diagram of the starter circuit showing connection of motor, starting switch, and battery. Diagrams will have greater value if the parts connected have the same relative position in the drawing as on the car.

9. Draw a diagram of the charging circuit showing connection of generator, ammeter, and battery.

10. Draw a diagram of the ignition primary circuit showing connection of battery, ammeter, ignition switch, primary coil, and timer.

11. Draw a diagram of the ignition secondary circuit, showing connection of secondary coil, distributor, and spark plugs.

12. Draw a diagram of the lighting circuits, showing connection of battery, ammeter, lighting switch, fuses, head and rear lamps.

NOTE: If a study is made of the home car, secure the Book of Instructions and Wiring Chart from the dealer.

Project 21 — FACTORS DETERMINING H.P. OF AUTOMOBILE ENGINES

Part I — Relation of H.P. to Piston Displacement

From the tables of automobile specifications given in the Appendix tabulate several six-cylinder engines and compute the horsepower per cubic inch of piston displacement for each engine when running at 1800 revolutions per minute.

Tabulation

Make and Model	No. of Cylinders	Piston Displacement	H.P. at 1800 R.P.M.	H.P. per Cu. In. Displacement
______	______	______	______	______
______	______	______	______	______
etc.				

Compute the average H.P. per cubic inch of displacement.

Do the results obtained indicate a definite relation between the horsepower and the piston displacement or size of engine?

Part II — Relation of H.P. to the Number of Cylinders

Make a similar table of several eight-cylinder engines and compute the horsepower per cubic inch of displacement when engine is running at 1800 revolutions per minute. Compute the average ratio and compare with the average of the six-cylinder engines.

Make a similar study and comparison with the sixteen-cylinder engines.

Do the results obtained indicate any definite relation between the horsepower and the number of cylinders?

Part III — Relation of H.P. to the Type of Engine

Compute the horsepower per cubic inch of displacement when running 1800 revolutions per minute of such engines that will determine if there is any advantage in the following comparisons:

(*a*) Long and short stroke in comparison with bore
(*b*) Location of valves (Over-head and L-head)
(*c*) Type of cooling system (Air and Water)

Part IV — Comparison of the Horsepower of Different Engines at the Same Car Speed

On double-ruled or cross-section paper, plot the six different horsepowers at the revolutions per minute given in the Appendix and draw the horsepower curve of the engine of each car to be compared.

Obtain the diameter of the tires, compute the circumference of the wheels and determine the number of revolutions per minute of the rear wheels when the car is going 30 miles per hour. Obtain the gear ratio of the car and determine the revolution per minute of the crankshaft at 30 miles per hour.

From the horsepower curve of the engine determine the horsepower at the R.P.M. of the crankshaft when the car is going 30 miles per hour.

Tabulation

Make and model of car	....	....	....
Diameter of tire	....	....	....
Circumference of wheel	....	....	....
R.P.M. of rear axle	....	....	....
Gear ratio in high	....	....	....
R.P.M. of crankshaft	....	....	....
H.P. at 30 mi. per hr.	....	....	....

APPENDIX A

TABLE 1

Numbers and Formulas

$$\pi = 3.1416$$
$$\pi^2 = 9.86965$$
$$\text{Circumference of circle} = 2\pi R$$
$$\text{Area of circle} = \pi R^2$$
$$\text{Surface of sphere} = \pi D^2$$
$$\text{Volume of sphere} = \tfrac{4}{3}\pi R^3$$
$$\text{Volume of cylinder} = \pi R^2 H$$

1 rod	= $16\frac{1}{2}$ feet	1 cu. ft.	= 1728 cu. in.
1 mile	= 320 rods	1 bushel	= 2150 cu. in.
1 mile	= 5280 feet	1 gallon	= 231 cu. in.
1 sq. ft.	= 144 sq. in.	1 H.P.	= 746 watts
1 acre	= 160 sq. rd.	1 B.T.U.	= 252 gram-calories
640 acres	= 1 sq. mi.	1 B.T.U.	= 778 foot pounds
		1 B.T.U.	= 1055 watt-seconds
		1 calorie	= 4.17 watt-seconds

TABLE 2

English and Metric Equivalents

1 meter	= 39.37 in.	1 inch	= 2.5400 cm.
1 meter	= 3.2809 ft.	1 foot	= 30.480 cm.
1 kilometer	= 0.6214 mi.	1 mile	= 1.6093 km.
1 sq. cm.	= 0.1550 sq. in.	1 sq. in.	= 6.4515 sq. cm.
1 sq. m.	= 10.764 sq. ft.	1 cu. in.	= 16.387 cu. cm.
1 cu. cm.	= 0.0610 cu. in.	1 fluid oz.	= 29.571 cu. cm.
1 cu. m.	= 1.3080 cu. yd.	1 dry qt.	= 1.101 liter
1 liter	= 0.9083 dry qt.	1 grain	= 0.0648 gm.
1 gram	= 0.0353 oz.	1 pound	= 453.59 gm.
1 kilogram	= 2.2046 lb.	1 ounce	= 28.349 gm.

TABLE 3

Specific Gravity — Grams per Cubic Centimeter

Alcohol	0.83	Iron, cast	7.23
Aluminum	2.67	Iron, wrought	7.78
Ash, dry	0.69	Lead, cast	11.36
Asphalt	2.50	Maple	0.76
Brass, cast	8.40	Marble	2.72
Brick	1.60–2.00	Mercury	13.60
Chalk	1.80–2.80	Oak, red	0.85
Coal	1.26–1.80	Oak, white	0.78
Copper, cast	8.83	Pine, white	0.55
German silver	8.43	Porcelain	2.38
Glass, crown	2.52	Quartz	2.65
Granite	2.65	Steel	7.82
Ice	0.92	Tin, cast	7.29
		Walnut	0.68
		Zinc, cast	7.00

TABLE 4

Decimal Equivalents for Fractions of Inch

Fractions	64ths	Decimal	Fractions	64ths	Decimal
	1	0.0156		33	0.5156
	2	0.0313		34	0.5313
	3	0.0469		35	0.5469
$\frac{1}{16}$	4	0.0625	$\frac{9}{16}$	36	0.5625
	5	0.0781		37	0.5781
	6	0.0938		38	0.5938
	7	0.1094		39	0.6094
$\frac{1}{8}$	8	0.1250	$\frac{5}{8}$	40	0.6250
	9	0.1406		41	0.6406
	10	0.1563		42	0.6563
	11	0.1719		43	0.6719
$\frac{3}{16}$	12	0.1875	$\frac{11}{16}$	44	0.6875
	13	0.2031		45	0.7031
	14	0.2188		46	0.7188
	15	0.2344		47	0.7344
$\frac{1}{4}$	16	0.2500	$\frac{3}{4}$	48	0.7500
	17	0.2656		49	0.7656
	18	0.2813		50	0.7815
	19	0.2969		51	0.7969
$\frac{5}{16}$	20	0.3125	$\frac{13}{16}$	52	0.8125
	21	0.3281		53	0.8281
	22	0.3438		54	0.8438
	23	0.3594		55	0.8594
$\frac{3}{8}$	24	0.3750	$\frac{7}{8}$	56	0.8750
	25	0.3906		57	0.8906
	26	0.4063		58	0.9063
	27	0.4219		59	0.9219
$\frac{7}{16}$	28	0.4375	$\frac{15}{16}$	60	0.9375
	29	0.4531		61	0.9531
	30	0.4688		62	0.9688
	31	0.4844		63	0.9844
$\frac{1}{2}$	32	0.5000	$\frac{16}{16}$	64	1.0000

TABLE 5

Coefficient of Sliding Friction

Brass on cast iron	0.19	Leather on metals, dry	0.56
Iron on iron	0.14–0.20	Leather on metals, wet	0.36
Iron on ice	0.016–0.032	Leather on metals, oily	0.15
Oak on oak	0.32–0.48	Metals on oak, dry	0.50–0.60
Leather on oak	0.27–0.38	Metals on oak, wet	0.24–0.26
Hemp on oak, dry	0.53	Iron on stone	0.30–0.70
Hemp on oak, wet	0.33	Wood on stone	0.40

TABLE 6

Strength of Metals — Pounds per Square Inch

Aluminum wire....	30000–40000	Platinum wire	50000
Brass wire.........	50000–150000	Silver wire	42000
Bronze wire.......	95000–140000	Steel wire, max....	460000
Copper, hard drawn	60000–70000	Steel, nickel......	250000
Gold wire.........	20000	Steel piano wire .	325000–390000
Iron, cast.........	13000–33000	Tin, drawn.......	4000–5000
Iron, hard drawn...	80000–120000	Zinc, cast	7000–13000
Iron, annealed.....	50000–60000	Zinc, drawn......	22000–30000

TABLE 7

Sines of Angles

Degree	Sine	Degree	Sine	Degree	Sine	Degree	Sine
1	0.017	24	0.407	47	0.731	70	0.940
2	0.035	25	0.423	48	0.743	71	0.946
3	0.052	26	0.438	49	0.755	72	0.951
4	0.070	27	0.454	50	0.766	73	0.956
5	0.087	28	0.469	51	0.777	74	0.961
6	0.105	29	0.485	52	0.788	75	0.966
7	0.122	30	0.500	53	0.799	76	0.970
8	0.139	31	0.515	54	0.809	77	0.974
9	0.156	32	0.530	55	0.819	78	0.978
10	0.174	33	0.545	56	0.829	79	0.982
11	0.191	34	0.559	57	0.839	80	0.985
12	0.208	35	0.574	58	0.848	81	0.988
13	0.225	36	0.588	59	0.857	82	0.990
14	0.242	37	0.602	60	0.866	83	0.993
15	0.259	38	0.616	61	0.875	84	0.995
16	0.276	39	0.629	62	0.883	85	0.996
17	0.292	40	0.643	63	0.891	86	0.998
18	0.309	41	0.656	64	0.899	87	0.999
19	0.326	42	0.669	65	0.906	88	0.999
20	0.342	43	0.682	66	0.914	89	0.999
21	0.358	44	0.695	67	0.921	90	1.000
22	0.375	45	0.707	68	0.927		
23	0.391	46	0.719	69	0.934		

TABLE 8

Indices of Refraction

Air.............	1.000294	Glass, crown........	1.53
Alcohol.........	1.36	Glass, flint..........	1.60
Benzine.........	1.49	Glycerine...........	1.47
Carbon disulphide	1.68	Ice.................	1.31
Diamond........	2.47	Turpentine..........	1.48
Ether...........	1.36	Water..............	1.34

TABLE 9

Melting Point — Degrees Centigrade

Aluminum	657	Nickel	1452
Carbon	Infusible	Platinum	1760
Copper	1065	Silicon	1200
Gold	1071	Silver	961
Iron, pure	1550	Sulphur	114.5
Lead	327	Tin	232
Mercury	–38.85	Zinc	419

TABLE 10

Boiling Point — Degrees Centigrade

Alcohol, ethyl	78.3	Ether	34.6
Alcohol, wood	64.7	Gasoline	70–90.
Acetic acid	118.	Glycerine	291.
Ammonia	–38.5	Mercury	357.
Benzene	80.	Sulphur	444.7
Bisulphide of carbon	46.2	Turpentine	159.
Chloroform	61.2	Water	100.

TABLE 11

Coefficients of Linear Expansion

Aluminum	0.0000222	Lead	0.0000280
Brass	0.0000188	Marble	0.0000079
Bronze	0.0000184	Pine	0.0000050
Copper	0.0000187	Platinum	0.0000089
Glass, tube	0.0000083	Silver	0.0000194
Gold	0.0000146	Steel, tempered	0.0000132
Iron, cast	0.0000113	Tin	0.0000230
Iron, wrought	0.0000122	Zinc	0.0000298

TABLE 12

Specific Heats

Aluminum	0.2185	Lead	0.0315
Brass	0.0940	Mercury	0.0335
Copper	0.0933	Nickel	0.1100
German silver	0.0946	Platinum	0.0320
Glass	0.1900	Quartz	0.1910
Gold	0.0320	Silver	0.0559
Ice	0.5040	Tin	0.0559
Iron	0.1125	Zinc	0.0935

TABLE 13

Specific Resistance — Ohms per Mil-Foot

Aluminum	18.7	Lead	120.3
Copper, annealed	10.45	Mercury	58.2
Copper, hard	10.65	Manganin	250–450.
German silver	181.0	Platinum	59.0
Iron	64.0	Silver	9.8
Iron, annealed	90.0		

TABLE 14

Diameter of Wires, American Wire Gauge (B. & S.)

Gauge No.	Diameter Mils	Diameter Mm.	Gauge No.	Diameter Mils	Diameter Mm.
0000	460.0	11.68	19	35.39	0.912
000	409.6	10.40	20	31.96	.812
00	364.8	9.266	21	28.45	.723
0	324.9	8.252	22	25.35	.644
1	289.3	7.348	23	22.57	.573
2	257.6	6.544	24	20.10	.511
3	229.4	5.827	25	17.90	.455
4	204.3	5.189	26	15.94	.405
5	181.9	4.621	27	14.20	.360
6	162.0	4.115	28	12.64	.321
7	144.3	3.665	29	11.26	.286
8	128.5	3.264	30	10.03	.255
9	114.4	2.906	31	8.93	.227
10	101.9	2.588	32	7.95	.202
11	90.74	2.305	33	7.08	.180
12	80.81	2.058	34	6.30	.160
13	71.96	1.828	35	5.61	.143
14	64.08	1.628	36	5.00	.127
15	57.07	1.450	37	4.45	.113
16	50.82	1.291	38	3.96	.101
17	45.26	1.150	39	3.53	.089
18	40.30	1.024	40	3.15	.079

Make and Model		Cylinders and Head	Bore and Stroke	Cylinder Disp.	Tax. H.P.	Max. H.P. and R.P.M.
Auburn	8–98	8–L	$3 \times 4\frac{3}{4}$	267	28.8	98 @ 3400
Austin		4–L	2.2×2	46	7.8	14 @ 3200
Buick	8–50	8–I	$2\frac{7}{8} \times 4\frac{1}{4}$	221	26.5	77 @ 3200
Buick	8–60	8–I	$3\frac{1}{16} \times 4\frac{5}{8}$	273	30.0	90@ 3000
Cadillac	V–16	16–I	3×4	452	57.5	165 @ 3400
Chevrolet		6–I	$3\frac{5}{16} \times 3\frac{3}{4}$	194	26.3	50 @ 2900
Chrysler	6	6–L	$3\frac{1}{8} \times 4\frac{1}{4}$	196	23.4	62 @ 3200
Chrysler	70	6–L	$3\frac{3}{8} \times 5$	268	27.3	93 @ 3200
Chrysler	Imp.	8–L	$3\frac{1}{2} \times 5$	385	39.2	125 @ 3200
Cord		8–L	$3\frac{1}{4} \times 4\frac{1}{2}$	297	33.8	125 @ 3600
De Soto	6	6–L	$3\frac{1}{4} \times 4\frac{1}{8}$	205	25.4	67 @ 3200
Dodge	6	6–L	$3\frac{1}{4} \times 4\frac{1}{4}$	212	25.4	68 @ 3400
Dodge	8	8–L	$3 \times 4\frac{1}{4}$	240	28.8	84 @ 3400
Durant	6–14	6–L	$3\frac{1}{4} \times 4$	199	25.4	70 @ 3100
Elcar	75–A	6–L	$2\frac{7}{8} \times 4\frac{3}{4}$	185	19.8	61 @ 3000
Essex	Super.	6–L	$2\frac{7}{8} \times 4\frac{1}{2}$	175	19.8	61 @ 3400
Ford	A	4–L	$3\frac{7}{8} \times 4\frac{1}{4}$	205	24.0	39 @ 2200
Franklin	15	6–I	$3\frac{1}{2} \times 4\frac{3}{4}$	274	29.4	87 @ 3000
Graham	Spec.	6–L	$3\frac{1}{4} \times 4\frac{1}{2}$	224	25.4	76 @ 3400
Gardner	136	6–L	$2\frac{7}{8} \times 4\frac{3}{4}$	185	19.8	70 @ 3500
Hudson		8–L	$2\frac{7}{8} \times 4\frac{1}{2}$	234	26.5	87 @ 3600
Hupmobile	C	6–L	$3\frac{1}{4} \times 4\frac{1}{4}$	212	25.4	70 @ 3200
Hupmobile	C	8–L	$2\frac{7}{8} \times 4\frac{5}{8}$	240	26.5	90 @ 3200
Jordan	80	8–L	$2\frac{7}{8} \times 4\frac{3}{4}$	247	26.5	80 @ 3000
Kissel	73	6–L	$2\frac{7}{8} \times 4\frac{3}{4}$	185	19.8	70 @ 3500
Lincoln		8–L	$3\frac{1}{2} \times 5$	384	39.2	120 @ 2900
Marmon	70	8–L	$2\frac{13}{16} \times 4\frac{1}{4}$	211	25.4	81 @ 3400
Nash	6–60	6–L	$3\frac{1}{8} \times 4\frac{3}{8}$	201	23.4	60 @ 2800
Nash	8–80	8–I	$3 \times 4\frac{1}{4}$	240	28.8	86 @ 3200
Oakland	8	8–L	$3\frac{7}{16} \times 3\frac{3}{8}$	251	37.8	85 @ 3200
Oldsmobile		6–L	$3\frac{3}{16} \times 4\frac{1}{8}$	198	24.4	65 @ 3350
Packard	826	8–L	$3\frac{3}{16} \times 5$	320	32.5	100 @ 3200
Peerless Mast.		8–L	$3\frac{3}{8} \times 4\frac{1}{2}$	322	36.5	120 @ 3200
Pierce Arrow		8–L	$3\frac{1}{2} \times 4\frac{3}{4}$	366	39.2	125 @ 3000
Plymouth		4–L	$3\frac{5}{8} \times 4\frac{3}{4}$	196	21.0	48 @ 2800
Pontiac		6–L	$3\frac{5}{16} \times 3\frac{7}{8}$	200	26.3	60 @ 3000

Make and Model		Cylinders and Head	Bore and Stroke	Cylinder Disp.	Tax. H.P.	Max. H.P. and R.P.M.
Reo	20	6–L	$3\frac{3}{8}$ x 5	268	27.3	85 @ 3200
Reo	30	8–L	$3\frac{3}{8}$ x 5	356	36.5	125 @ 3300
Studebaker		6–L	$3\frac{1}{4}$ x $4\frac{1}{8}$	205	25.4	70 @ 3200
Studebaker	D.	8–L	$3\frac{1}{16}$ x $3\frac{3}{4}$	221	30.0	78 @ 3400
Studebaker	C.	8–L	$3\frac{1}{16}$ x $4\frac{1}{4}$	250	30.0	101 @ 3200
Stutz	LA.	6–O	$3\frac{3}{8}$ x $4\frac{1}{2}$	242	27.3	85 @ 3150
Willys	6–97	6–L	$3\frac{1}{4}$ x $3\frac{7}{8}$	193	25.4	65 @ 3400
Willys	8–80	8–L	$3\frac{1}{8}$ x 4	245	31.3	80 @ 3200
Willys-Knight		6–S	$3\frac{3}{8}$ x $4\frac{3}{4}$	255	27.3	87 @ 3200

SPECIFICATIONS — AUTOMOBILE CHASSIS — 1931

Make and Model		Wheel Base In.	Size Rim Tire	Gear Ratio High	Transmission Ratios * 2nd	Low	Rev.	Weight 4–D Sedan
Auburn	8–98	126	17–6.00	4.45	1.68	2.87	3.76	3590
Austin		75	18–3.75	5.25	1.73	3.13	3.84	1130
Buick	8–50	114	18–5.25	4.55	1.75	3.00	3.86	3170
Buick	8–60	118	19–5.50	4.45	1.75	3.03	3.65	3795
Cadillac	V–16	148	19–7.00	4.39	1.51	2.50	3.00	5850
Chevrolet		109	19–4.75	4.10	1.77	3.32	4.20	2685
Chrysler	6	116	19–5.00	4.66	1.82	3.04	3.65	2695
Chrysler	70	118	18–5.50	3.82	2.19	3.38	3.49	3590
Chrysler	Imp.	145	18–7.50	3.82	3.82	2.35	3.38	4705
Cord		$137\frac{1}{2}$	18–7.00	4.80	1.68	2.84	3.45	4705
De Soto	6	113	19–4.75	4.33	1.79	2.76	3.44	2705
Dodge	6	114	19–5.00	4.66	1.79	2.76	3.44	3040
Dodge	8	118	18–5.50	4.60	1.79	2.75	3.44	3340
Durant	6–14	112	19–5.00	4.40	1.77	3.32	4.20	2790
Elcar	75–A	117	19–5.00	4.90	1.77	3.07	4.00	2940
Essex	Super	113	19–5.00	5.40	1.96	3.24	4.17	2805
Ford	A	$103\frac{1}{2}$	19–4.75	3.77	1.85	3.13	3.75	2462
Franklin	15	125	19–6.50	4.73	2.41	3.55	3.21	4220
Graham	Spec.	115	18–5.50	4.10	2.41	3.54	3.10	3150
Gardner	136	122	19–5.50	4.45	2.32	3.75	3.20	3250
Hudson		119	18–5.50	4.63	1.92	2.91	3.45	3550

* To obtain final gear ratios multiply ratio in high by transmission ratio.

Make and Model		Wheel Base In.	Size Rim Tire	Gear Ratio High	Transmission Ratios * 2nd	Low	Rev.	Weight 4-D Sedan
Hupmobile	6–C	113½	19–5.50	4.70	1.65	2.87	3.44	2905
Hupmobile	8–C	118	19–5.50	4.55	1.68	2.87	3.76	3175
Jordan	80	120	18–5.50	4.90	1.82	3.43	3.64	3590
Kissel	73	117	18–6.00	4.89	1.69	3.11	4.10	3212
Lincoln		145	19–7.00	4.58	1.76	3.08	3.66	4790
Marmon	70	112¾	19–5.50	4.90	1.83	3.04	3.65	3833
Nash	6–60	114¼	19–5.00	5.10	1.75	3.06	3.77	2800
Nash	8–80	121	18–5.50	4.45	1.69	3.08	4.17	3360
Oakland	8	117	18–5.50	4.55	1.63	3.06	3.44	3140
Oldsmobile		113½	18–5.25	4.56	1.63	3.06	3.44	2950
Packard	826	127½	19–6.50	4.69	1.84	3.14	2.54	4479
Peerless	Mast.	125	19–6.00	4.45	2.46	4.01	3.46	4521
Pierce Arrow		134	19–6.50	4.42	2.08	3.12	2.72	4523
Plymouth		110	19–4.75	4.38	1.79	2.75	3.44	2565
Pontiac		112	19–5.00	4.55	1.77	3.32	4.21	2705
Reo	20	120	18–6.00	4.07	1.67	3.13	3.81	3700
Reo	30	130	18–6.50	3.77	1.38	2.29	2.84	4305
Studebaker	6	114	19–5.25	4.73	1.82	3.22	3.65	2950
Studebaker	D.	114	19–5.25	4.73	1.82	3.22	3.65	3155
Studebaker	C.	124	19–6.00	4.73	1.68	2.87	3.76	3520
Stutz	LA.	127½	19–6.00	4.75	1.68	2.87	3.76	4200
Willys	6–97	110	19–5.00	4.60	1.53	2.70	3.33	2682
Willys	8–80	121	19–5.50	4.40	1.75	3.06	3.76	3303
Willys-Knight		121	18–6.00	4.18	1.75	3.06	3.76	3582

* To obtain final gear ratios multiply ratio in high by transmission ratio.

Horsepower of Automobile Engines at Different Speeds

Make and Model	No. of Cylinders	H.P. at given R.P.M.					Maximum H.P. at R.P.M.
		600	1200	1800	2400	3000	
Auburn 8–98	8–L	20.0	41.0	61.5	81.2	92.5	98 @ 3400
Buick 8–50	8–I	16.4	35.5	53.0	67.8	76.0	77 @ 3200
Buick 8–60	8–I	21.0	45.0	68.5	85.0	90.0	90 @ 3000
Cadillac V–16	16–I	35.0	72.0	104.0	134.0	157.0	165 @ 3400
Chevrolet	6–I	13.7	27.5	41.2	49.0		50 @ 2900
Chrysler	6–L	13.5	28.2	41.0	53.2	61.0	62 @ 3200
Chrysler Imp.	8–L	28.0	59.5	89.0	113.0	123.0	125 @ 3200
Dodge	6–L	14.0	30.0	46.0	59.0	67.0	68 @ 3400
Dodge	8–L	17.0	37.0	54.0	68.0	78.0	84 @ 3400
Durant 6–14	6–L	15.0	31.5	46.5	59.5	69.5	70 @ 3100
Essex	6–L	13.0	27.0	40.5	50.5	58.5	61 @ 3400
Ford A	4–L	13.5	28.5	35.0			39 @ 2200
Franklin 15	6–I	20.0	40.0	68.0	80.0	87.0	87 @ 3000
Graham Spec.	6–L	16.0	34.0	51.0	66.0	74.0	76 @ 3400
Hudson	8–L	17.5	36.5	52.5	67.5	80.0	87 @ 3600
Marmon 70	8–L	16.0	35.0	52.5	67.0	77.0	81 @ 3400
Nash 8–80	8–L	18.5	36.5	54.6	73.0	85.0	86 @ 3200
Oakland	8–L	18.0	40.0	58.0	77.0	82.0	85 @ 3200
Oldsmobile	6–L	14.0	29.0	44.0	57.5	64.0	65 @ 3350
Pontiac	6–L	14.0	32.0	45.0	56.0	60.0	60 @ 3000
Reo 20	6–L	20.0	39.0	59.0	75.0	84.0	85 @ 3200
Reo 30	8–L	26.0	52.0	78.0	100.0	122.0	125 @ 3300
Studebaker Six	6–L	14.0	30.5	45.0	58.0	68.0	70 @ 3200
Studebaker Dict.	8–L	15.5	34.5	52.0	68.0	75.0	78 @ 3400

APPENDIX B

A Suggested List of Apparatus for the Experiments

Experiment	
1	Rectangular block, 2 x 4 x 16 inches. A half-meter stick.
2	Vernier caliper. Brass cylinder (200-gram mass).
3	Micrometer screw. Steel ball, diameter half-inch.
4	Spring balance, 18 oz. capacity, and light pan. Rectangular block, 2 x 2 x 4 inches. Catch bucket of overflow apparatus. Support rod, two V-clamps, and seven-inch spike.
5	Harvard trip balance. Block of weights, 1 gm.–500gm. Block and bucket of Experiment 4.
6	Support rod, clamp, and spike. Spring balance, 64 oz. Two-pound and four-pound masses. Half-meter stick with holes at 10, 25, and 49.
7	Support rod, clamp, and small cross rod. Two spring balances. One-, two-, and four-pound masses. Half-meter stick.
8	Trip balance. Small wood prism. Half-meter stick. Block of weights. Small cylinder of unknown weight.
9	Support rod, two clamps, spike. Two spring balances, 64 oz. capacity. Two single pulleys. Four-pound mass.
10	Trip balance. Inclined-plane apparatus. Meter stick. Block of weights. (Hall-carriage and spring balance)
11	Automobile jack, screw type (Walker 216B). Support rod, clamp, and spike. Spring balance, 64 oz. capacity. Spring balance, 30 lb. capacity. Small cylinder. Lever, 1 x 2 x 18 inches. Table clamp.
12	Grooved wheel with handle (wheel of rotovac pump). For axle, cut two inches from the threaded end of a 19 mm. support rod. Place axle in receptacle in table top or in a tripod base clamped to table. Two spring balances, 30 lb. capacity. (64 oz. balance may be used for one.) Two table clamps. Three feet of one-fourth inch rope.
13	Pine board 1 x 6 x 18 inches. Pine block, 2 x 4 x 5 inches with screw eye in end. Spring balance, 64 oz. Two- and four-pound masses. Sandpaper.
14	Board and block of Experiment 13. Two- and four-pound masses. Spring balance, 64 oz. Support rod and clamp. A spike driven in the edge of the board near one end serves as a means of clamping the board at any height.

Experiment

15 Support rod, clamp and spike. Spring balance, 18 oz., and light pan. Six-inch battery jar. Overflow can and bucket. A sinking block and a floating cylinder.

16 Apparatus of Experiment 15. Large specimens of brick, cannel coal, stone, etc.

17 Support rod and clamp. Burette clamp. U-tube about eight inches long. Rubber tubing. Half-meter stick.

18 A closed manometer about one foot long. Other apparatus as in Experiment 17.

19 Support rod and clamp. Meter stick and light pan. Half-meter stick. Block of weights. A right-angle clamp with a 19 mm. V-opening may be used to clamp the meter stick in a horizontal position.

20 Table clamp. Spring balance, 30 lb. Spike. Micrometer screw. Copper wire No. 26. Iron and brass wire No. 32.

21 Three spring balances, 64 oz. Connecting cords. Blocks with hooks and table clamps. Compass and protractor.

22 Support rod, two V-clamps and spike. Two spring balances, 64 oz. A two-pound mass. Half-meter stick with hole near one end and screw eye in other end. Compass and protractor.

23 Support rod and clamp. Board and block of Experiment 13. Four-pound mass. Compass and protractor. Spring balance, 64 oz.

24 Grooved plank, five feet long. Heavy ball and lycopodium powder. For a powder sifter place three layers of cheesecloth over wide-mouth bottle. Meter stick and a half-meter stick. Blocks of Experiment 1. The plank should have a guide, or a vertical surface extending from edge to within three-quarters of an inch of the center of groove, for releasing the ball.

25 Support rod and p ndulum clamp. Fine silk cord. One and one-half inch iron and wood balls. Meter stick. Watch.

26 A nine- or ten-foot pendulum. Use fine steel or brass wire and a two- or four-pound mass for bob. Meter stick or tape. Stop watch.

27 Apparatus the same as in Experiment 24.

28 Support rod, right-angle clamp, and a large universal clamp. Glass tube, 45 cm. length and 4 cm. diameter. Hydrometer jar, size 2 x 12 inches. Tuning fork, 256 vibrations.

29 Two support rods, two right-angle clamps, and two burette clamps. Three-inch glass funnel and two Y-tubes. Two heavy wall tubes, 3 in. and 30 in. Three light wall tubes, 12, 25, and 29.5 in. Two tuning forks, 384 and 512 vibrations.

30 Two table clamps. Spring balance, 30 lb. Piano wires, Nos. 24 and 26. Small iron ring and washer. Wood prism, 2 in. Half-meter stick. Two tuning forks, 384 and 512 vibrations.

31 Plane mirror, 4 x 15 cm. Two wood blocks. Foot rule. Pins.

32 Cylindrical mirror, 5 x 10 cm. Rule, pins and compass.

33 Same as Experiment 32.

34 Spherical mirror, concave and convex, 12 cm. diameter, mounted. Optical bench consisting of support rod, two end supports, three index clamps, mounted screen, and gas jet.

35 Six-inch battery jar. Table clamp. Compass. Protractor. Refraction board 1 x 5 x 7 inches with small groove sawed across one side and the two edges near the center. A small hole to fit a $1\frac{1}{4}$-in. nail drilled near lower left-hand corner and in groove about two inches from left-hand edge.

36 Glass plate, 7 cm. x 7 cm. x 6 mm., two edges polished and two ground. Compass. Protractor. Pins. Rule.

37 Equilateral glass prism. Compass. Protractor. Pins. Rule.

38 Optical bench of Experiment 34. Lens holder, mounted. Double convex lens, 5 cm. diameter, 12.5 cm. focus. Double concave lens, 5 cm. diameter, 20 cm. focus.

39 Boiling chamber and burner. Linear expansion apparatus with micrometer.

40 Boiling apparatus. Calorimeter. Centigrade thermometer. Balls of iron, brass, and iron, $1\frac{1}{2}$ in. Trip balance. Block of weights.

41 Support rod, clamp, and spike. Calorimeter. Thermometer. Balance. Weights. Iron ball, $\frac{3}{4}$ in. Chromel wire, No. 28.

42 Calorimeter, thermometer, balance, and weights. Snow.

43 Boiling apparatus. Apparatus of Experiment 42.

44 Support rod, right-angle clamp, and burette clamp. Tripod and burner. Copper boiler or 800 cc. beaker. Thorp gauge.

45 Two bar magnets, $\frac{3}{4}$ x 6 in. Magnet board, 9 x 11 in., with a single groove on one side and two grooves 2 in. apart on other side. Iron filings and sifter.

EXPERI-
MENT

46 Voltmeter, 0–10 range. Student demonstration battery. Five different elements and five solutions or electrolytes.

47 Voltammeter, 0–10 range. Two dry cells. Key. Four feet of German-silver wire, No. 30 (wire on Wheatstone bridge may be used). Micrometer screw.

48 Wheatstone bridge. Dry cell. Key. Resistance box. Four feet German-silver wire, No. 30. Student galvanometer.

49 Voltammeter, 0–10 range. Resistance box. Two dry cells and key.

50 Apparatus of Experiment 49.

51 Apparatus of Experiment 49 with three dry cells.

52 Apparatus of Experiment 51.

53 Compass. Large iron nail. Dry cell and key. Block, 2 x 2 x 4.

54 Electric doorbell. Two keys and dry cell.

55 Telegraph key and sounder combined. Support rod, clamps, and wire.

56 A source of current of 2 or more volts. Student cell with 2 copper, 2 lead, and 1 carbon electrode. Solutions of copper sulphate and sulphuric acid. Salt.

57 Extension cord with key socket. Support rod, right-angle clamp, and burette clamp. Calorimeter and thermometer. Balance and weights. 60-watt lamp.

58 Student galvanometer. Two insulated copper wires, No. 18, seven feet and three feet long. Large wire nail. Two bar magnets. Dry cell and key. Three-inch piece of broom handle.

59 St. Louis motor, improved. A.C. a mature and electromagnet attachment. Galvanometer. Resistance box. Dry cell, connecting wires and key.

60 Apparatus of Experiment 58.

61 Table of Specifications — Automobile Engines. Appendix.

62 Blue prints of power and torque curves may be secured from any automobile manufacturer.

63 Table of Specifications — Automobile Chassis. Appendix.

64 The wiring chart of the electric system of any automobile can be secured through the Automobile Digest, 22 East 12th St., Cincinnati, Ohio.